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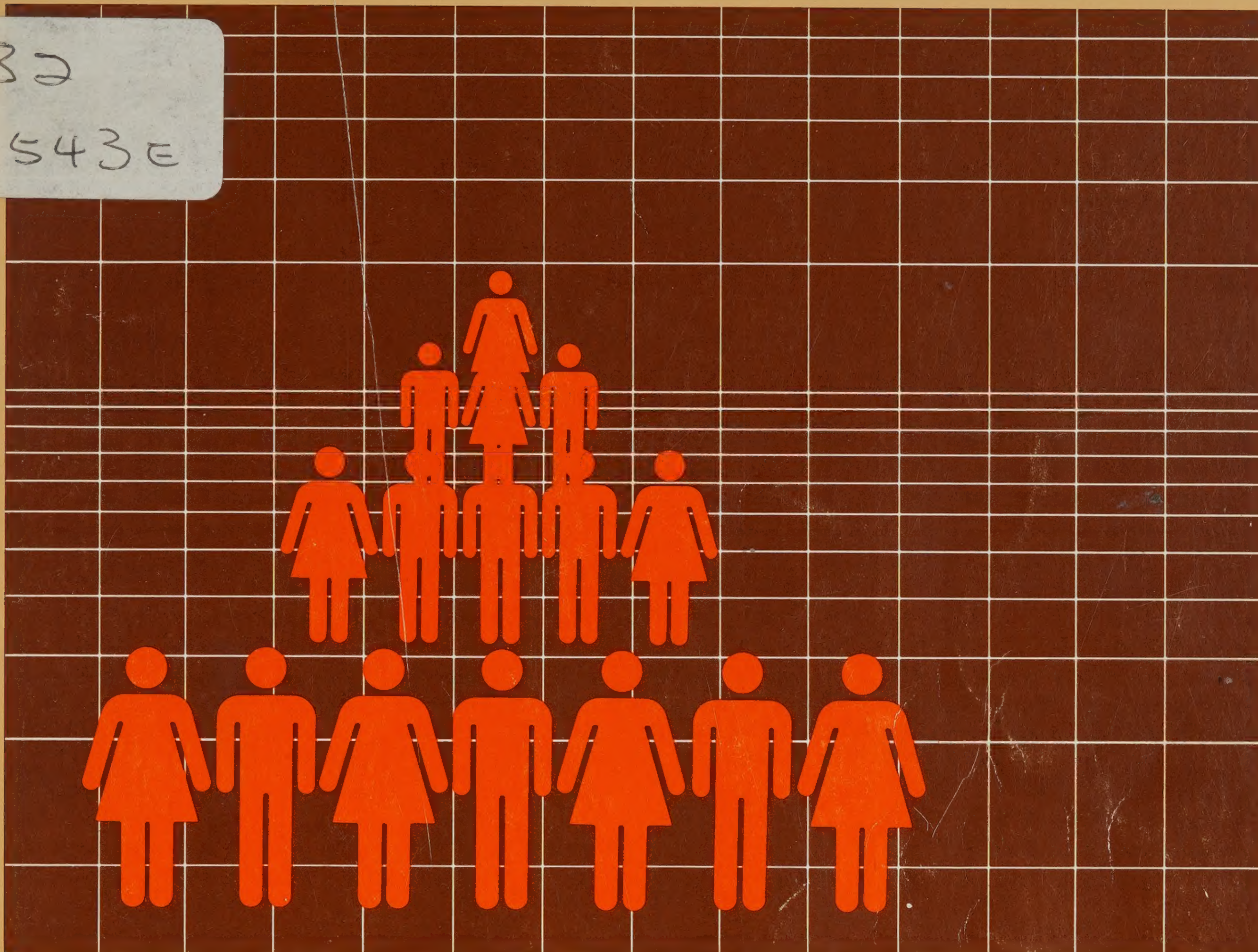

DEMOGRAPHIC AND HEALTH INDICATORS

PRESENTATION AND INTERPRETATION

Yves Péron and Claude Strohmenger

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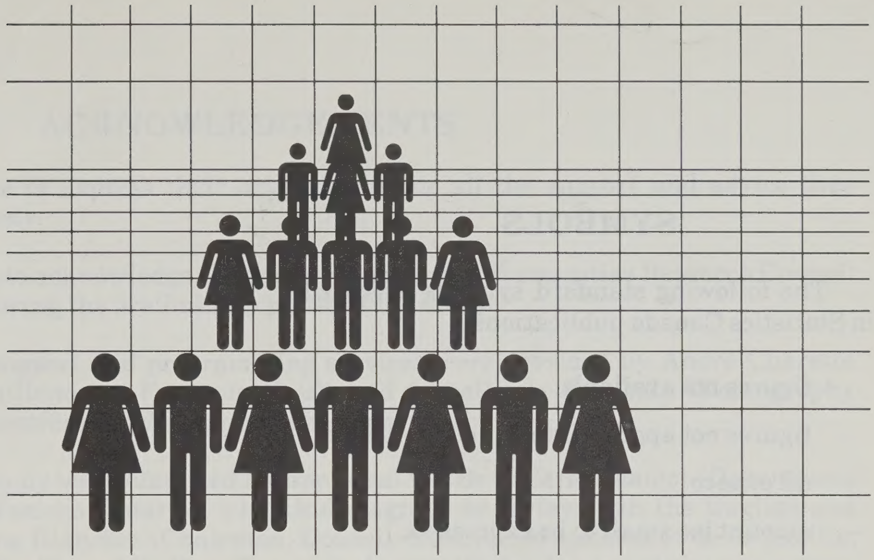

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Yves Péron and Claude Strohmenger

Statistics Canada
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Research and Analysis Section

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PREFACE

Providing a level of health care that will ensure a long and active life for the largest possible number of people has been and remains one of the major social objectives of modern governments. After the decline of infectious diseases and the attendant premature mortality, however, the pursuit of this objective seemed increasingly difficult - and increasingly costly - as the proportion of chronic diseases, frequently incurable and debilitating, grew. In response, there has been new research on the health status of populations, suggesting new measures of health status in addition to the classical indices of morbidity and mortality.

Thus, it is becoming more common for statistics on the health of populations to cover all four of the following aspects: exposure to risk factors which vary widely with environment and lifestyle; information on incidence and prevalence of disease, which is essential to estimate health care needs; prevalence of disability (a consequence of ill health), which is increasingly associated with quality of life; and mortality itself because its timing and causes are largely a reflection of individual lifestyles. This book is concerned primarily with statistical measures of these four phenomena and the aggregation of these measures into more sophisticated indices. All these statistical tools are useful in public health as they provide valuable information about the population's level of health, the scope of its health problems and needs, and the effectiveness of actions taken.

As the recent development of community health care shows, however, a great deal of sociodemographic data must be compiled and summarized before health programs and policies can be prepared. First, the size and structure of a population and the changes it is undergoing impose constraints that cannot be ignored for long, a fact that has become particularly evident in aging populations. Secondly, health promotion programs nearly always involve individuals and families. Accordingly, this report also contains demographic indices that provide information about population structures and dynamics and the incidence of major social developments such as the steady decline of traditional marriage patterns, the increasing frequency of family break-up due to divorce and the drop in fertility.

There is a three-part description of each demographic index or health indicator: 1. Its definition and a brief description of its main functions, 2. Its interpretation, 3. A technical discussion that explains how it is calculated. This format should allow ready reference for readers with different interests: students and teachers of demography and health sciences, public health workers and, more generally, anyone who wishes to acquire a better understanding of population and health statistics.

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INTRODUCTION

Demography deals with the occurrence of the main events of personal and family life within human groups, as well as the population structures which result from them. The contribution of demography is thus essential to the understanding of any society and its evolution.

Because of the nature of the events it studies, demography provides the link between the social and biomedical sciences, bringing to both of these sciences a body of methods and results which are indispensable and enriching.

Therefore, indices developed in demography are widely used outside of that discipline, notably in the field of public health.

DEMOGRAPHIC INDICES IN PUBLIC HEALTH

Following the example of Goldberg and his collaborators,[1] a parallel may be drawn between the activities of doctors and those of public health authorities, if one substitutes the individual patient on the one hand by the population as a whole on the other (Figure 1). Public health authorities must therefore:

1. acquire a good understanding of the population and how it is changing,

2. make an overall evaluation of its level of health,

3. identify and classify its health problems and needs,

4. decide what measures should be taken to alleviate these problems and satisfy these needs,

5. evaluate the effects of these measures.

All this calls for the collection, analysis and synthesis of a considerable amount of quantitative and qualitative information about the population.

Since this mass of information is so voluminous and disparate, public health authorities are looking for a synthesis in the form of a limited body of indices which will quickly show the most significant aspects of the health situation, and enable them to make the appropriate decisions and to foresee all the implications of these decisions.

Demographic indices are among those most commonly adopted for this purpose. The use of these demographic indices appears quite normal when assessing a population's state and change, or when identifying and classifying certain health problems. However, somewhat more surprising is the use of these indices to evaluate the level of health of a population or to estimate the utility of certain actions in the health field. Like many other indices, demographic indices often have a two-fold function: on the one hand, they measure a particular phenomenon, and, on the other, they provide information about other unmeasured phenomena.

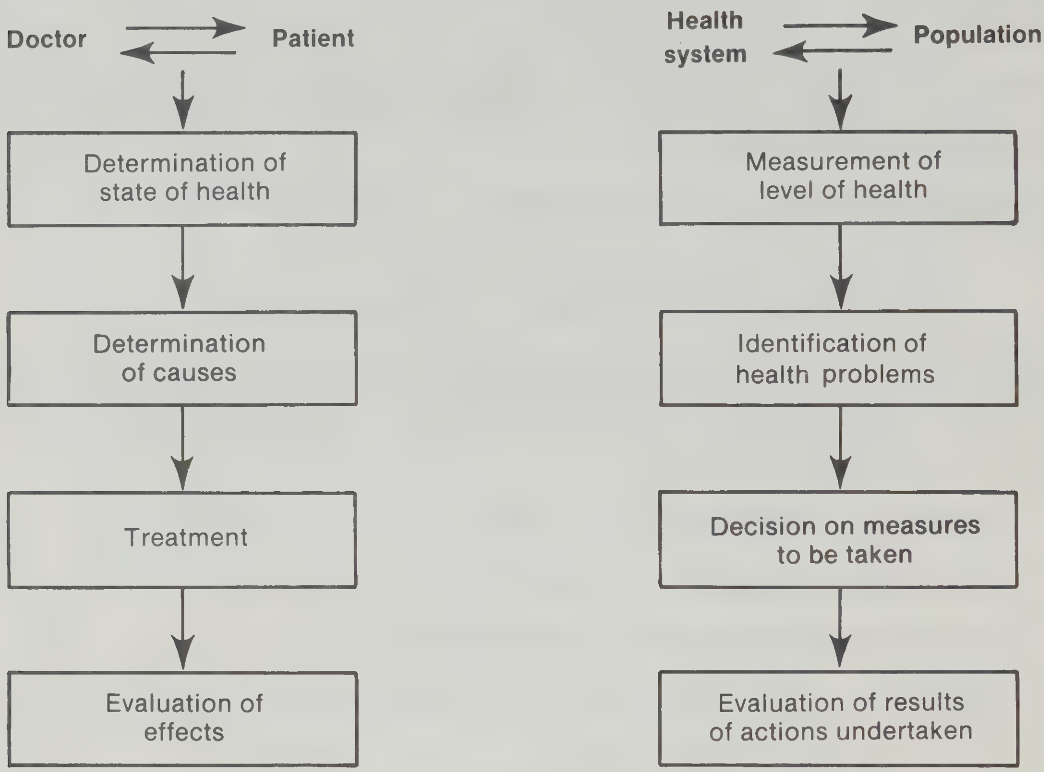
This observation leads us to establish a clear distinction between the functions of descriptor and indicator, which is the purpose of the next section.

---

1 Goldberg, M., **et al.**, "Indicateurs de santé et 'sanométrie': les aspects conceptuels des recherches récentes sur la mesure de l'état de santé d'une population", **Revue d'épidémiologie et de santé publique,** Vol. 27, Nos. 1 and 2, 1979, pp. 51-68 and 133-152.

Figure 1

Parallel Between the Activity of the Doctor and that of Public Health Authorities



Source: Adapted from Goldberg, M. **et al., op. cit.**, pp. 52-53.

DESCRIPTORS AND INDICATORS

An Example from Everyday Life

The ordinary barometer is a device which registers the successive movements of a metal capsule enclosing a metal spring, in a vacuum. When looking at the dial of this instrument, however, it is observed that this single indication refers to two different phenomena: atmospheric pressure and weather. What are the relationships between the reading obtained and these two phenomena?

Atmospheric pressure is a measurable physical phenomenon, since it is the pressure exerted on the ground by air. It may thus be measured using instruments which indicate only its specific effects. The movement of the metal capsule of the barometer is in fact a specific effect of atmospheric pressure. When this pressure is high, it compresses the capsule and the spring it contains; when the pressure drops, the spring uncoils and pushes out the walls, giving the capsule a shape which corresponds to the level of pressure exerted by the air around it. In this way, each change of the capsule can be associated to a specific level of atmospheric pressure. The indication given by the various movements of the metal capsule of the barometer is thus a technical process which allows one to measure the first of the two phenomena under consideration.

As opposed to atmospheric pressure, weather is a complex and non-quantifiable physical phenomenon. There is no accurate way for it to be measured. It is known, however, that atmospheric pressure plays an important, although not the only, role in determining it. Specific

types of weather correspond to various levels of atmospheric pressure: higher pressure is associated with good weather, and lower pressure with bad weather, while medium pressures correspond to changing weather. Knowing the atmospheric pressure and whether it is rising or falling, a valuable **indication** can be derived regarding the current weather and its likely development.

The important thing to note here is that the number shown by the barometer needle has two different functions. First, it tells what the atmospheric pressure is (quantifiable phenomenon) and, second, it provides an **indication**, i.e. a rough but useful piece of information, of what the weather is (non-quantifiable phenomenon). This two-fold function may also be observed for many statistical indices. They may be interpreted as descriptors of a quantifiable phenomenon, or as indicators of a non-quantifiable phenomenon.

Descriptors

In this study , the term "descriptor" will be used to designate the overall synthetic indices and graphic representations used in the description of a quantifiable phenomenon or of one of its dimensions. Indices which serve as links among phenomena will also be called descriptors.

In general, an index is analysed as a descriptor when all that is under study are the relations of the index with the quantifiable phenomenon whose manifestations were used to develop the index. In such an analysis, certain questions may be asked, notably the following:

- can the index provide a valid measure of the phenomenon in question?
- does the index react to changes in the phenomenon?
- are variations in the index due only to changes in the phenomenon?
- do the various values of the index always serve to distinguish between different situations?

The quality of a descriptor basically depends on the answers to these questions.

Indicators

The term "indicator" will be used in this study to designate any synthetic index whose values are used as points of reference in evaluating the state or development of a non-quantifiable phenomenon.

One way of obtaining an indicator is to identify a quantifiable phenomenon whose state and development are linked as closely as possible to the state and development of a non-quantifiable phenomenon. The descriptor of the first phenomenon then serves as the indicator of the second. In this way, descriptors of mortality have been, and still are, used as indicators of the state of health of a population. In some cases, the descriptors of various phenomena may be combined or aggregated in order to improve the quality of the indicator. Expectation of life in good health, which combines data on mortality and disability, is a good example of this approach to developing an indicator.

Another method is to determine what are the exhaustive and mutually exclusive dimensions of the phenomenon, then choose variables which are representative of these dimensions, and finally propose a weighting system which enables every situation encountered to be summarized by a single value. This value is arbitrary and may only be understood by reference to a standard and a scale. Indices of the state of health of individuals are good examples of the application of this method.

Regardless of the method used to obtain it, an indicator should not be taken as a true measure of the phenomenon for which it has been chosen. Life expectancy, for instance, is a measure of the longevity rather than the health status of a population. It provides only a qualitative indication of the latter phenomenon, based on the fact that to various levels of life expectancy correspond states

of health which are themselves quite distinct. What is expected of an indicator is not that it measure the phenomenon it was chosen to represent, but that it vary in a coherent fashion with the states of this phenomenon. Since the number of states which can effectively be distinguished is generally limited, each of these states is represented by a given segment of the range of variation of the indicator, rather than by a single value. For this reason, although the indicator should always be calculated as carefully and precisely as possible, any interpretation of the results obtained will be based less on its exact value than on the interval into which it falls.

The information that is to be derived from an indicator is normally not neutral. If it is to be of any use to planners in their area of concern, the indicator should permit the following:

(a) to classify the situations encountered on a scale going from most unfavourable to most favourable,

(b) to determine whether the development of the phenomenon over time is towards an improvement or a deterioration of the situation.

This presupposes that the various states of the phenomenon have been classified beforehand according to a pre-established scale of preferences and that the spread of possible values of the indicator is compatible with the hierarchy thus obtained. The indicator then serves to support a value judgement on the state and development of the phenomenon.

Having defined the concept, let us now turn our attention to the qualities that are required of an indicator.

Qualities of an Indicator

Among the qualities that may be sought in an indicator, the four qualities of validity, sensitivity, specificity and reliability are particularly important. These are in fact comparable to those already mentioned with respect to descriptors.

There is a natural tendency, often due in part to the name given to statistical indices, to reduce a phenomenon to the type of numerical expression normally given for it. Health, for instance, is held to be what is measured by health indicators. One can question this tendency by raising the problem of the **validity** of the proposed measure. This problem is normally stated as follows: "Are we really measuring what we believe we are measuring or what we wish to measure?" Such a statement of the problem of validity is quite appropriate in the case of descriptors, although slightly less so in the case of indicators. In the latter case, the question would no doubt be more clearly and appropriately stated in the following manner: "Does the type of measure adopted as an indicator really provide the entire range of values necessary to evaluate the state and development of the phenomenon for which it was chosen?". In most cases, the reply given will be qualified, since validity is mainly a question of degree.

The ideal indicator should tell the user immediately of any change, no matter how slight, in the situation under consideration. It must thus be **sensitive**, i.e. vary significantly and rapidly when changes appear in the phenomenon it represents. It should also be **specific**, that is, vary only when the phenomenon itself varies.

In order that valid temporal and spatial comparisons may be carried out, an indicator should also be **reliable**. This means that a given value of the indicator should always correspond to the same state of the phenomenon, no matter what additional circumstances may present themselves. In other words, a given value of the indicator must invariably signify the same thing.

In practice, the indicators at our disposal satisfy these various requirements only in a very imperfect way. These requirements are nevertheless useful in selecting indicators, as are other criteria which will now be described.

Other Selection Criteria

Among the most commonly mentioned criteria, the following will be discussed:

- **availability** or **feasibility**,
- **stability of sources** and **objectivity of calculation**,
- **intelligibility**.

An indicator that is already available is obviously preferable to any other indicator of equal quality and, of two equivalent indicators not currently available, it is best to choose the one whose calculation would involve the least technical, administrative, legal and financial difficulties. Before using an indicator, care must be taken to ensure that its various values have been obtained from data which are comparable in kind and quality, and that the method of calculation used is objective and accepted by specialists. Insofar as possible, the indicator should be intelligible, that is, a non-specialist should be able to understand it.

ORGANIZATION AND OBJECTIVES OF THE STUDY

This report is divided into two parts, both to take into account the information requirements of public health authorities and to comply with the distinction that has been made between descriptors and indicators.

The first part is devoted to the descriptors of the population state and of the population change. Chapter 1 is an overview of the principles of analysing demographic phenomena and the difficulties involved. Next are presented descriptors of the intensity and tempo of these phenomena (Chapter 2), descriptors of the state of the population (Chapter 3) and descriptors of population change (Chapter 4).

The second part deals with the use of demographic descriptors as indicators of the health status of the population. After briefly describing the concepts underlying the development of the various measures of health status (Chapter 5), indicators of levels of health (Chapter 6), indicators of health problems (Chapter 7) and indicators specific to certain life stages (Chapter 8) are presented.

The indices presented are of three types: demographic indices per se, health indicators developed from these indices including some new indicators (e.g., potential years of life lost, life expectancy in good health), and certain epidemiological indicators used by demographers in analysing mortality.

A three-part presentation is adopted for the more important indices:

1. a brief description identifying the index and giving its definition and functions as well as, where applicable, its objectives;

2. an illustration, including a commentary aimed at demonstrating the interest of the index and clarifying its interpretation;

3. a technical or methodological discussion, featuring the principles according to which the index is calculated.

This presentation should make this book more accessible to persons of various backgrounds.

It is hoped that this study may serve as a reference work for all those who, by reason of their activity in the health field, have need to understand or use demographic indices.

PART I

DESCRIPTORS OF THE POPULATION STATE AND OF POPULATION CHANGE

CHAPTER 1

CLASSIFICATION OF DEMOGRAPHIC DESCRIPTORS

Since, in the field of public health, the population plays the role of the patient, it is generally recognized that study of the structure and dynamics of a population is indispensable to identifying its health requirements and planning for health services. Workers in the public health field are thus frequently in a position where they must use statistical instruments developed by demographers. The first part of this study will thus consist of a brief presentation of the most commonly used demographic indices.

It should be emphasized that these indices are presented at this point only as descriptors of the state and change of the population, since it is only in the second part of this work that they will be adopted as indicators of health status. For the moment, then, our purpose is only to describe as precisely as possible the objectives, content, and proper demographic use of the descriptors discussed.

The descriptors have been grouped in three distinct chapters: descriptors of the intensity and tempo of demographic phenomena, descriptors of the state of the population, and period descriptors. This organization calls for some preliminary explanation, and this will be found in the following discussion of the field of demography, demographic events and phenomena, demographic variables and structures, and the analysis of the demographic situation at given points in time.

The Field of Demography

Considering its most specific and constant characteristics, demography may be said to be the study of the quantitative replacement of human populations[1] and related issues. Thus conceived, demography includes a wide variety of research and activities in a field which extends from the counting of persons and the principal events of their lives, to the development of population policies.

The demographer normally defines a population as the group of persons living in a given territory.[2] This population is seen as being in a continuous process of renewal through births, deaths and migration. The continuous occurrence of these events constantly modifies the population state, that is its size and structure. The state of the population is not simply a reflection of past processes, it is also a major factor in determining its future change in the short and medium term. Population state and population change are in fact interdependent and thus constitute a system.

This system is obviously not a closed one. It is linked to many other elements of the life of the society, and these links are widely studied in the areas of qualitative, economic or social demography. As is the case for scientists in other disciplines, the demographer begins by postulating the autonomy of the system under study. This working hypothesis is absolutely necessary in order to develop practices and methods specific to the discipline. The following sections will examine the main implications of this hypothesis.

Demographic Events and Phenomena

The size of a population varies over time due to births and deaths as well as by migration, that is, exchanges with other populations. Since these events are central to population change, they are clearly demographic in nature.

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1 One should nevertheless note the existence of areas of demography dealing with populations such as animals, plants or cells.

2 Studies dealing with the replacement of certain sub-populations are normally given specific names, such as ethnolinguistic demography, medical demography, demography of school populations, etc.

As well, in most societies, human reproduction is largely influenced by legal or customary arrangements. Consequently, marriages, divorces and widowhood have a tremendous impact on the renewal of the population depending on their frequency and the ages at which they take place. Thus, these also constitute demographic events.

From birth to death, it is thus the most important vital events which are of interest to the demographer. But, these events also attract, to a greater or lesser degree, the attention of other scientists: biologists, epidemiologists, doctors, ethnologists, sociologists, etc. Given the attention that these events attract from so many different disciplines, one is inevitably led to ask what is the specific nature of the demographic approach to these facts of everyday life.

Since the demographer's primary concern is to link population change to the state of the population, the key interest is in establishing relationships between the number of events observed and the size or structure of the population in which these events take place. It is thus by means of the frequency of occurrence of these events in the population as a whole that they are studied in demography. These are thus perceived as collective events, called "demographic phenomena", which are the object of our analysis.

From tables showing the frequency of deaths in the population, the demographer can derive statistical constants which illustrate the collective reality of death - or **mortality** - in a manner which transcends the apparent uncertainty of personal destinies. In the same way, collective behaviour with respect to marriage (**nuptiality**), **divorce** or procreation (**fertility**) emerges from the highly varied background of individual behaviour. In short, moving from the individual to the collective by examining the frequency with which events occur in the population as a whole, the demographer can establish a certain regularity in events from the apparent disorder of their everyday manifestations.

Up until the Second World War, demographers thought that analysing annual data on population change was sufficient in order to develop the basic tools for describing demographic phenomena. They were convinced that the chronological progression of annual indices was a faithful reflection of the inevitable and far-reaching transformation of collective behaviour engendered by the continual progress in industrialization, urbanization and standards of living. They were thus perplexed to observe that, during and after the war, the traditional downward trend had been replaced by an unaccountable rise in most indices. From this emerged a common concern in the discipline: if existing theories on the historical evolution of behaviour were not to be called into question, better analyses would have to be carried out on demographic phenomena in order to develop better descriptive tools.

Fertility was the first phenomenon to be thus re-examined. It quickly became evident that, in order to isolate demographic groups with relatively consistent behaviour, the order in which events occurred throughout the lives of the members would have to be taken into account, as well as the lapse of time between the various occurrences. It was thus necessary to add to the classic distinction between married and unmarried women, an additional distinguishing feature, that of parity. In the same way, it became indispensable to further subdivide the traditional breakdown by age to show duration of marriage and, whenever applicable, the time interval since the birth of the previous child. It was thus possible not only to verify the fact that the more similar the demographic background of women the more consistent their behaviour during a given year would be, but also to confirm the necessity of enhancing classical fertility studies through an analysis of the gradual constitution of lifetime fertility. During the same period, the careful study of the fertility history of several female birth cohorts[3] or several marriage cohorts[4] showed, among other things, that certain historical circumstances could disrupt the usual constitution of lifetime fertility by causing women to have their children earlier or later in the childbearing years. Consequently, fertility indices calculated during years of war or economic crisis are seriously affected by the postponement of marriages and the temporary slowdown in the formation of families, while those calculated in years of return to peace or prosperity reflect an upswing in marriages and the making up for postponed births. It accordingly became clear that any acceleration or slowdown in the constitution

[3] In demography, a birth cohort is a group of persons born during a given calendar year or period of 12 consecutive months.
[4] A marriage cohort includes all couples married during a given calendar year or period of 12 consecutive months.

of lifetime fertility would necessarily modify trends shown by changes in period descriptors of fertility. These descriptors of annual fertility thus proved to be more complex in nature than had been previously imagined, since they combined into one single measure the effect of changes in the timing of births and in the level of completed fertility.

By studying in more detail the measurement of fertility and extending this approach to other phenomena, demographers have made far-reaching changes in their patterns of analysis. The result has been a new way of describing demographic phenomena.

Phenomena had long been analysed by looking at only one temporal variable for individuals: their ages. Even when marital status was used to identify the group exposed to a given phenomenon, the time lapse since marriage, divorce or widowhood was only rarely taken into account. This is no longer the case. Legitimate fertility is now studied on the basis of duration of marriage rather than of the age of the woman. Frequency of remarriage among divorced persons is calculated based on the time lapse since divorce, with age being only the second determining factor in the analysis. As a general rule, it is the most recent of the events necessarily preceding the one under study that is given preference in establishing the beginning of the temporal dimension to be used in analysing the phenomenon concerned. Ordinarily, the time elapsed since the occurrence of this event is more discriminating than any other temporal variable.

This better grasp of the natural sequence of vital events enables one to derive descriptors which are particularly simple and concrete. Among all the events which necessarily precede the one under study, the most recent marks the beginning of exposure to the phenomenon studied and, consequently, the time elapsed since its occurrence represents the duration of exposure. Designating as O the event observed and as A the most recent of the events which necessarily precede it, the following two questions can be asked about the occurrence of O:

(a) among persons who have already experienced A, what is the proportion of those who will eventually experience O and, on the average, how many times?

(b) how can occurrences of O be distributed according to the time elapsed since the occurrence of A?

The relevance of these two questions may be easily illustrated using one of many possible examples: if O is divorce, A is marriage, then the first questions anyone asks in connection with divorce are certainly about the proportion of couples who eventually divorce and the distribution of divorces by duration of marriage. The numerical answer to the first question is the descriptor of the **intensity** of the phenomenon, since it provides the average number of occurrences per person exposed. The answer to the second question gives the distribution of occurrences of the phenomenon throughout the period of exposure, i.e. its **tempo**. The phenomenon is thus characterized by the total frequency of its occurrences and the manner in which these are distributed over time.

The reader has no doubt already deduced from the nature of the questions asked that intensity and tempo can only be calculated once the entire history of the phenomenon is known. As long as individuals have not come to the end of their exposure period, it is clear that the total number of events cannot be known. Descriptors of the intensity and tempo of demographic phenomena, like those described in Chapter 2, must thus be derived from the observation of groups for which the history of the phenomenon under study is completed. It is thus necessary to resist the long tradition by which the period descriptors calculated from events recorded during a given calendar year are used to describe a group whose history is not yet completed. The fourth section of this chapter will return to this issue.

Demographic Variables and Structures

The demographic situation of individuals at a given point in time is determined by the series of demographic events that they have already experienced. The nature, number and timing of these events permit the classification of individuals in terms of the values of these various demographic variables. Some of these variables, such as marital or migratory status, are qualitative and are defined according to the occurrence or non-occurrence of certain events. Others, and these are more

numerous, are quantitative: time elapsed since certain events took place (age, marriage duration, length of residence in the country, ...), time interval between the occurrences of two events (age at marriage, birth interval, etc.) or the number of events of a given type (number of children ever-born or cumulative fertility, number of previous migrations, etc.).

The distribution of the inhabitants of an area according to the values of one or more of these demographic variables, constitutes one of the demographic structures of the population of that territory. The data required for the study of these demographic structures are obtained from censuses, and the estimates which are derived from them. The structures most commonly used deal with age, marital status and migratory status. In addition, demographic variables are often combined with non-demographic variables to illustrate population structures of particular interest, such as demolinguistic, sociodemographic or demo-economic structures.

The demographic structures of the population may be studied in two quite different ways. The first, and perhaps the most common, requires the use of only the most basic techniques of descriptive statistics. The second method, more recent, is based on approaches specifically developed for the analysis of demographic phenomena.

A good example of how the first method is used would be the description of the composition of the population by age and sex. This composition is illustrated by the well-known population (or age) pyramid, which is nothing more than a particular form of histogram. The classic descriptors, such as the proportion of young and old persons or the age dependency ratio, are merely the relative sizes of given groups. Demographic skill only comes into play when it comes to interpretating the graphic representation and the value of the indices.

Things are somewhat different when one looks at other demographic structures. The most basic techniques of descriptive statistics may of course serve to illustrate one or another of their characteristics, but these techniques are quite insufficient. Only knowledge of the procedures used in analysing demographic phenomena will make it possible to properly organize the collection and combination of data and their graphic or numerical treatment.

For example, the composition of the population by marital status is mainly determined by the prior occurrence of three phenomena: marriage, divorce and widowhood. This does not mean that precise conclusions may immediately be drawn on the past evolution of these phenomena. From the number of widowed, divorced or married persons, one cannot infer the number of widowhoods, divorces or marriages already experienced by persons who are still part of the population at the time of observation. The only thing about which one can be certain is that all widowed, divorced and married persons have once entered into a first marriage. Therefore, the nuptiality of single persons is the only phenomenon for which the total number of prior occurrences in the lives of the persons under observation are known. Assuming that exposure to this phenomenon ceases, for all practical purposes, around age 50, its intensity among persons who have passed that age can be calculated. Among younger persons, however, the proportion ever-married represents only a fraction of the intensity of the phenomenon, and the more recent exposure to the phenomenon is, the smaller the fraction will be. These few preliminary remarks are nevertheless sufficient to advance the analyses on two levels. On the one hand, from the composition of the population by marital status, which is a complex structure resulting from the interaction of several phenomena, it is possible to derive a simpler structure. In this case the simpler structure is the distribution of the population between married and single, which depends on one phenomenon only. On the other hand, by describing this new structure by means of a series of appropriate indices - the proportions of persons ever-married at each age - it is possible to clarify the relationships of this structure to the intensity and tempo of the phenomenon on which it depends.

Census figures sometimes provide a distribution of ever-married women by children ever-born. For these women, this gives the total number of previous manifestations of fertility. The average number of children already born constitutes the intensity of the phenomenon when it is calculated for groups of women who have already passed childbearing age, whereas for other groups of women it constitutes only a more or less important fraction of this intensity depending on the age of the women. In addition, the examination of the distributions themselves, rather than their average values, permits the study of the pattern of cumulative fertility. The experience acquired in

analysing other phenomena shows that it is preferable to treat the constitution of cumulative fertility as a succession of stages - birth of a first child, birth of a second child, etc. - with the completion or non-completion of a given stage determining the final size of the family. Thus, completing the first two stages but not the third would lead to a two-child family. To describe the constitution of the cumulative fertility of women who have completed their reproductive period, one would calculate the following proportions: proportion of women who have had at least one child, proportion going on to have a second child among those who have had one child, etc. These proportions, which are called parity progression ratios, are of greater interest than the relative frequency figures derived from the size distribution of families. In particular, they enable a good analysis to be made of progress in voluntary birth control among modern populations.

As a result of all this, the descriptors of the state of the population to be described in Chapter 3 fall into two different categories: some merely summarize an existing situation, while others are aimed at bringing to light the underlying demographic mechanisms.

Period Descriptors

Period measures are the various synthetic indices obtained by a more or less detailed analysis of population change over a given year or other short period. Of all demographic indicators, these are the best-known and most commonly used. Paradoxically, they are also the most difficult to interpret.

The first group of descriptors are simple ratios between the number of events recorded in a given year and the average size of the population at the middle of that year. Examples of these are the crude birth rate and the crude death rate. Comparison of the values calculated for these rates over a long period or between different populations is generally hampered by the difficult problem of interference by demographic structures which are independent of the phenomenon under study.

The second category of descriptors is made up of annual "sums of event frequencies".* The total fertility rate, obtained by summing age-specific general fertility rates, is a familiar example. These synthetic indices may be calculated for all phenomena with the exception of mortality, and the calculation is normally quite simple. If, for each annual interval of the period of exposure to the phenomenon, one has both the number of events recorded during the year of observation and the number of persons (or couples) surviving and having ever been exposed to the phenomenon, one simply calculates the ratio between these two figures and then sums the rates thus obtained. The following example will demonstrate how this is done. A ratio could be established between the number of first marriages observed at a given age and the number of men (or women) of that age at the middle of the year of observation. The synthetic nuptiality index for never-married persons would then be the sum of the rates thus calculated for all ages between 15 and 49. As will be seen in Chapter 4, changes in these synthetic indices over time reflect changes in both the intensity and tempo of the phenomenon in question.

A third and final category of period descriptors involves certain descriptors of mortality, in particular the life expectancies at various ages.

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* Following Louis Henry, these are known in French as "sommes des événements réduits" (i.e. reduced to a common denominator, normally per 1,000). In the case of the total fertility rate, for example, the "events" would of course be the number of births, and the result would be expressed per 1,000 women.

CHAPTER 2

DESCRIPTORS OF THE INTENSITY AND TEMPO OF DEMOGRAPHIC PHENOMENA

The intensity of a demographic phenomenon can only be calculated once exposure of a group of persons or couples to the phenomenon under study is complete, i.e., once each member of the group has been exposed to the phenomenon throughout the entire time necessary for its manifestation. The same is true of tempo, which must, in addition, be determined by taking as its temporal beginning the moment at which exposure to the phenomenon begins. These two requirements are factors in choosing the demographic groups most appropriate for calculating the intensity and determining the tempo of each phenomenon. They also justify the care that needs to be taken in the organization of observations and calculations in order to resolve the difficult problem of persons who are accidentally lost to observation during the period of exposure to the phenomenon. These problems will be considered briefly before going on to the main objective of this chapter, which is devoted essentially to a presentation of the most common descriptors.

Longitudinal Analysis of Demographic Phenomena

A demographic phenomenon manifests itself by the occurrence of a certain type of demographic events in the population: mortality is manifested by deaths, nuptiality by marriages, fertility by live births, etc. These occurrences may be analysed in two different ways:

- the occurrence of events in the population within a given year or other short period can be considered; this type of analysis is called "cross-sectional" or "period" analysis;
- alternatively, one can consider the occurrence of events within a group of persons who would ideally be kept under observation throughout the period of their lives when the phenomenon is likely to be manifest; this is called "longitudinal" analysis.

Cross-sectional analysis provides the period descriptors to be presented in Chapter 4, but only longitudinal analysis can give the descriptors of the intensity and tempo of demographic phenomena which will be presented in this chapter.

The demographic groups chosen for longitudinal analysis are "cohorts", that is, groups of persons or couples who have experienced the same demographic event during a given calendar year or, more generally, during a given 12-month period. The group is most often a birth cohort or a marriage cohort. A birth cohort is made up of all the persons born during the same year, while a marriage cohort includes all couples married during the same year.

Where statistical data permit, the cohort chosen for longitudinal analysis of a given demographic phenomenon will be the one which includes all those persons or couples who reached at the same time that particular phase in their life cycle when the phenomenon could manifest itself. The birth cohort will be chosen for the study of mortality and migration, since all persons are exposed from birth to these phenomena. The birth cohort would also be chosen for the analysis of first marriage and general fertility.[1] Since it cannot be known at what moment a person may decide to marry for the first time, nor when a woman becomes able to procreate, the demographer must replace these moments by those at which such persons arrive at the minimum age for marriage or the minimum age for maternity. Obviously, all members of a given birth cohort reach these minimum ages during the same year. Conversely, but applying the same principle, the marriage cohort would be used to study divorces and legitimate fertility i.e., the fertility of married couples. In analysing remarriage, a phenomenon which can occur only after a divorce or widowhood, the cohorts of newly divorced or widowed persons would be used.

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[1] By definition, general fertility is the phenomenon which manifests itself through the total number of live births, irrespective of the marital status of parents.

Once the appropriate cohorts have been chosen, a longitudinal analysis will be based on the reconstitution of their demographic history in order to develop appropriately concrete and significant descriptors of the manifestation of the phenomenon in question. Let us now see how this is done.

Intensity and Tempo of Demographic Phenomena

Considering a demographic phenomenon which manifests itself by events called O, normal observation will indicate:

(a) that the events O are experienced only by persons or couples who have already experienced a prior event, called A,

(b) that events O occur within a maximum limit of **d** years after the occurrence of A.

This suggests that the phenomenon must be described from two points of view. In the first place, its "intensity" must be measured, either by the proportion of persons or couples who, once they have experienced A, eventually also experience O, or, in certain cases, by the average number of events O later experienced by these same persons or couples. In the second place, the "tempo" of the phenomenon must be determined by establishing the distribution of occurrences of O according to the time elapsed since the occurrence of A. Table 1 shows this intuitive definition of the intensity and tempo of various demographic phenomena arrived at by the process just described.

In order to determine the values to be assigned to the intensity and tempo of a given demographic phenomenon over time, it is necessary to reconstitute the history of a series of cohorts made up of persons or couples who have already experienced event A. Each cohort must, of course, be observed during the **d** years during which the phenomenon is likely to occur. If, during the **d** first years of existence of the cohort, there were no disturbing influences and thus the members of the cohort were exposed only to the phenomenon under study, a recording of events O which take place within the cohort would give the total number of possible manifestations of this phenomenon, and one could easily deduce from this the intensity and tempo. The intensity would then be equal to the ratio of the total number of events O to the size of the cohort at the time of its formation, and the tempo would be given by the distribution of these events O according to the time elapsed since the cohort was formed. Unfortunately, this is never the case. In the course of time, certain members of the cohort experience other events which interrupt their exposure to the phenomenon. Thus, premature death subtracts certain members of a cohort from the number still exposed to the risk of marriage or maternity, while early widowhood interrupts the growth of the family and exposure to the risk of divorce. These examples should suffice to show that the occurrence of such "disruptive" events interferes with direct observation of the full manifestation of a phenomenon within a cohort. The events O effectively experienced by the cohort are fewer in number than those which would result from complete exposure of all members to the phenomenon under study. How, then, can the intensity and tempo of the phenomenon be calculated?

One solution, which would apply to a non-fatal phenomenon, would be to limit the observation to members of the cohort surviving at the end of the period of exposure. All these persons, or all these couples, were certainly exposed to the full cycle of the phenomenon. A thorough retrospective survey would enable one to collect all the data required on occurrences of event O within this group of survivors in order to calculate the intensity and determine the tempo of the phenomenon. Thus, one would estimate the intensity of the nuptiality of never-married persons by the proportion of persons ever married among those surviving at age 50, and the intensity of general fertility by the average number of children born to women still alive at that age.

A second solution, still applying to non-fatal phenomena, is based on first calculating the average number of events O experienced per year lived by members of the cohort in each of the **d** first years of its existence. These averages would then be applied to a group which has hypothetically escaped any disruptive events, enabling an estimate to be made of the intensity and tempo of the phenomenon. The case of general fertility is a good illustration of how this method is applied.

TABLE 1. Method of Describing Some Demographic Phenomena

Demographic phenomenon	Manifestation of phenomenon (event O)	Last event necessarily preceding(A)	Maximum time during which phenomenon may occur(d)	Intensity	Tempo
Mortality	Death	Birth	Approx. 110 years	Proportion of persons who ever die, i.e. 100%	Distribution of deaths by age
Nuptiality of single persons	First marriage	Reaching minimum age for marriage	Approx. 35 years	Proportion of persons who ever marry	Distribution of first marriages by age
Nuptiality of widowed and divorced	Remarriage	Widowhood or divorce	Approx. 15 years	Proportion of widowed or divorced persons who ever remarry	Distribution of remarriages by time elapsed since widowhood or divorce
Divorce	Divorce	Marriage	Approx. 30 years	Proportion of couples who ever divorce	Distribution of divorces by duration of marriage
General fertility	Live birth	Reaching minimum age for maternity	Approx. 35 years	Average number of children born to a woman during the childbearing period	Distribution of live births by age of mother
Legitimate fertility	Legitimate live birth	Marriage	Approx. 25 years	Average number of children born to married couples	Distribution of legitimate live births by duration of parents' marriage
Emigration	Leaving country	Birth	Approx. 40 years	Proportion of persons who ever emigrate	Distribution of departures by age of emigrants

A third solution, which would apply to non-renewable events, involves first calculating the annual risk of occurrence of event O for persons who have not yet experienced it at the beginning of each of the **d** first years of existence of the cohort. Properly combined, these risks enable one to estimate the occurrence of events O in the cohort if all members escaped any disruptive events. It is then possible to derive an estimate of the intensity and tempo of the phenomenon involved. Studies of mortality, and of nuptiality in the case of first marriages, are good examples of this.

What should especially be retained from the above discussion is the fact that there are several methods for calculating the intensity and tempo of a demographic phenomenon, but all of them have the same goal, i.e. to characterize the occurrence of events O in a cohort, assuming that only the phenomenon under study comes into play.

Presentation of Descriptors

In the remainder of this chapter, a number of descriptors of the intensity and tempo of various demographic phenomena will be presented. The list of phenomena intentionally omits those for which the user will only rarely find the expected descriptors: divorce, widowhood, nuptiality of the widowed and divorced, and migration. Included, however, are descriptors of reproduction, even though this is not properly speaking a phenomenon, but a combination of two other phenomena, general fertility and mortality. It was felt that the frequent references to these descriptors justified their being included in this chapter.

D-01: MEAN LENGTH OF LIFE OF A BIRTH COHORT

I DESCRIPTION

Target Groups

Mean length of life may be calculated for a group of persons born alive during a given year (birth cohort) or during a given period (group of birth cohorts), provided that all these persons are now deceased (extinct birth cohort or extinct group of birth cohorts).

Definition

The mean length of life of a birth cohort is the average number of years lived by its members between the moment of their birth and that of their death.

Synonym

Expectation of life at birth for a cohort.

Function

Since the length of a person's life after birth is equal to age at death, the mean length of life of a birth cohort is equal to the average age at death of that cohort. Mean length of life is a statistical summary of the age-specific distribution of deaths, and is therefore a descriptor of the tempo of mortality of the birth cohort.

Similar Descriptors

Mean length of life should not be confused with two apparently similar descriptors: probable length of life, or the maximum age reached by half the members of the cohort (median age at death), and normal age at death, or the age at which are recorded the greatest number of deaths among adults or the elderly (modal age at death). These two descriptors are rarely used and will not be discussed in this study.

II COMMON USES

Mean length of life of birth cohorts is a descriptor that is rarely available due to lack of appropriate statistics. In most countries, including Canada, vital statistics are too recent to enable one to draw a complete picture of the mortality experienced by one or more birth cohorts over the period of a century. Parish registers and genealogies must be examined to fill in gaps in the data. A study carried out in this way by Charbonneau[2] showed that persons of European origin born in Canada prior to 1730 lived an average of 35.5 years.

For thousands of years, the mean length of life of men and women remained at a little over 20 years. Had it been less than that, the survival of mankind would have been in jeopardy. In the West, it rose to 25 or 30 years at the end of the Middle Ages, with fluctuations due to mortality crises caused by famines, epidemics and wars. In the history of humanity as a whole, the increase in the mean length of life is a recent phenomenon. Even in an elite group such as the British peerage, major lasting increases were only recorded for cohorts born after 1750. This marked progress was not confined to the upper classes alone. From that period on, it spread to the entire populations of what are now the developed countries, but even so, the traditional inequality of social groups in the face of death has not been eliminated.

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2 Charbonneau, H., **Vie et mort de nos ancêtres. Étude démographique** ("Démographie canadienne" Series, No. 3), Montréal, Les Presses de l'Université de Montréal, 1975, 267 p.

TABLE 2. Evolution of the Mean Length of Life of Members of the British Peerage, Groups of Birth Cohorts, 1550-74 to 1925-49

Birth cohort group	Males	Females	Birth cohort group	Males	Females
	years			years	
1550-1574	36.5	38.2	1750-1774	44.5	45.7
1575-1599	35.3	38.1	1775-1799	46.8	49.0
1600-1624	32.9	35.3	1800-1824	49.2	51.7
1625-1649	31.2	33.2	1825-1849	52.1	58.4
1650-1674	29.6	32.7	1850-1874	54.7	62.8
1675-1699	32.9	34.2	1875-1899[1]	53.8	67.0
1700-1724	34.4	36.2	1900-1924[2]	60.2	70.0
1725-1749	38.6	36.7	1925-1949[3]	61.9	71.0

1 Mortality after age 80 assumed the same as in previous cohort group.
2 Mortality after age 53 assumed the same as in previous cohort group.
3 Mortality after age 30 assumed the same as in previous cohort group.
Source: Hollingsworth, T.H., "The Demography of the British Peerage", **Population Studies**, Vol. XVIII(2), Supplement, November 1964, pp.56-57.

Where health conditions vary rapidly over time, as has been the case for the past two centuries in Western countries, the mean length of life of a birth cohort cannot be used as a summary of a well-defined level of mortality. Thus, roughly speaking, the mean length of life of the 1800 cohort reflects infant and child mortality during the early 19th century, adult mortality between 1820 and 1860 and mortality of the elderly during the last four decades of the century. The concept of mean length of life will nevertheless still be used to obtain a synthetic index of mortality conditions prevalent at a given time. This will no longer be the mean length of life of a real cohort, but that of a synthetic cohort, the members of which are assumed to have been exposed, from one age to another, to the risks of death calculated from observations made during a given year or a given short period. This descriptor will be discussed in Chapter 6 under the heading "expectation of life at birth (period approach)", since this is obviously a period descriptor.

It should be noted that increasing the mean length of life of successive cohorts has a positive effect on population growth, and this descriptor should thus be used together with the net reproduction rate in estimating cohort replacement (see Descriptor D-07 in this chapter dealing with the "net reproduction rate").

III TECHNICAL DISCUSSION

Life Tables

Charbonneau studied the demographic history of a group of 4,631 individuals making up a representative sample of all persons of European origin born in Canada prior to 1730. Table 3 shows the gradual extinction of this group under the effect of mortality.

Two columns are devoted to the transcription of the observed data. The "Survivors V_x" column gives the number of persons still alive on the birthdays x which serve as the lower limit of the various age groups, or 4,631 at birth, 3,655 on the first birthday, 3,312 on the fifth birthday, etc. The "Deaths D_x" column gives the number of persons deceased in the various age groups: 976 before the first birthday, 343 between the first and fifth birthdays, 126 between the fifth and 10th birthdays, etc. It may easily be seen that one can move from a given V_x to the next by subtracting from the first V_x the D_x shown on the same line. This means that, from one age to another, the number of survivors V_x decreases only through death; the author has thus been able to arrive at that exceptional situation where no other event disrupts the observation of mortality.

TABLE 3. Life Table for the First Generations of Canadians of European Origin

Age x	Observed data: Survivors V_x	Observed data: Deaths D_x	Life table functions: Death probability (per 1,000) ${}_aq_x = D_x/V_x$	Life table functions: Survivors S_x	Life table functions: Deaths $d(x,x+a)$	Life table functions: Life expectancy e_x
0	4,631	976	211	1,000	211	35.5
1	3,655	343	94	789	74	43.9
5	3,312	126	38	715	27	44.3
10	3,186	94	30	688	21	40.9
15	3,092	151	49	667	33	37.2
20	2,941	207	71	634	45	33.9
25	2,733	196	72	589	42	31.3
30	2,538	228	90	547	49	28.5
35	2,309	207	90	498	45	26.1
40	2,103	225	107	453	48	23.4
45	1,878	187	100	405	40	20.9
50	1,691	209	124	365	45	17.9
55	1,482	244	165	320	53	15.1
60	1,238	249	201	267	54	12.6
65	989	267	270	213	58	10.1
70	722	276	382	155	59	8.0
75	446	202	453	96	43	6.4
80	244	160	656	53	35	4.5
85	84	69	821	18	15	3.3
90	15	11	733	3	3	
95	4	4				
100	0					

Source: Vie et mort de nos ancêtres, op. cit., p. 125.

It is clear that these observed data cannot be immediately compared with similar data for a group whose size at birth was very different. For this reason alone, the data should be converted into figures per 1,000, 10,000 or 100,000 persons at birth. This conversion leads to the construction of life tables.

The life table indicates the number of survivors at various birthdays x and the number of deaths in the various age intervals bounded by these birthdays. The figures will, however, be given in this case for a group of 1,000 persons at birth and not 4,631. These figures S(x) and d(x,x + a) are obtained simply by dividing by 4,631 the corresponding V_x or D_x figures, and then multiplying the result by 1,000. Among this base of 1,000 people, the series S(x) gives the proportion of persons still alive at various birthdays x, while the series d(x,x + a) gives the distribution of deaths by age, or the tempo of mortality.

More traditionally, the life table is drawn up by first calculating death probabilities. These probabilities ${}_aq_x$ are nothing more than the ratios obtained by dividing the number of deaths D_x recorded between two birthdays x and x + a by the number of persons still alive on the first of these birthdays (V_x). The first probability is thus equal to 976 divided by 4,631, the second to 343 divided

by 3,655, etc. These probabilities are estimates of the risk of death in the various age intervals for persons still alive at the beginning of each interval. These probabilities can then be used to simulate the gradual extinction with age of a group of 1,000 persons at birth. This would be done as follows:

- 1,000 newborns exposed to a risk of death of 0.211 for the first year of life would yield 211 deaths before the first birthday, when the survivors would number only 789;
- 789 survivors on the first birthday exposed to a risk of death of 0.094 before their fifth birthday would yield 74 deaths during the four following years, and only 715 of this group would then be alive on their fifth birthday;
- etc.

Leaving aside rounding errors, this method would yield S(x) and d(x,x+a) series completely identical with those obtained by the first method, and these series may thus be interpreted in the same manner.

Calculating Life Expectancy

The table also shows life expectancies on various birthdays, that is, the average number of years of life remaining for survivors on these birthdays. It can thus be seen that persons who had reached their 30th birthday lived an average of 28.5 more years. Let us now look at how these life expectancies are calculated.

Taking an age interval of length **a**, bounded by birthdays x and x+a, the following information is found in the table:

- the number of survivors at birthday x, i.e. S(x);
- the number of survivors at birthday x+a, i.e. S(x+a);
- the number of deaths in the interval, i.e. d(x,x+a) = S(x)-S(x+a)

The number of years lived in that interval can then be calculated, distinguishing between deceased and non-deceased. If, to simplify matters, it is assumed that deaths were spread evenly throughout the interval, the total number of years lived by the deceased is equal to:

$$\frac{a}{2} \cdot [S(x) - S(x+a)]$$

The non-deceased, that is, those surviving on birthday x+a, have for their part necessarily lived a total of:

$$a \,.\, S(x+a)$$

Adding the above two quantities, one obtains:

$$a \,.\, \frac{S(x) + S(x+a)}{2}$$

The sum of the years lived in a given age interval is thus equal to the product of the length of the interval by the arithmetic mean of survivors at the beginning and end of the interval.

Repeating this calculation for all the intervals following birthday x and adding all the results together, one obtains the "total number of years lived after birthday x". Dividing this sum by the number of survivors on birthday x, one obtains the "life expectancy at birthday x". The value for x=0 is the "life expectancy at birth" or "mean length of life".

The Problem of Losses from Observation

The example given is, as mentioned, quite exceptional in the sense that observation of mortality is not disrupted by the occurrence of other events. In all honesty it must be admitted that this is because the author had previously estimated the age at death of persons who were lost from observation due to emigration or deficiencies in the birth and death registration systems. This observation has thus been adjusted to account for the disturbance caused by losses from observation.

The fact that some persons can be lost from observation leads one to replace the two series V_x and D_x by the following three series:

- V'_x or survivors still under observation at birthday x,
- D'_x or deaths effectively observed during the interval commencing on birthday x,
- E'_x or losses from observation in the interval commencing on birthday x.

It is clear that V'_x is lower than V_x due to the absence of persons still alive but who could not be counted. It is also clear that D'_x is lower than D_x because of the non-registration of deaths occurring among those persons who were already lost from observation. In these conditions, calculation of life tables necessarily begins with the calculation of age-specific death probabilities. But how does one calculate these probabilities?

Taking $_aq_x$ as the risk of death during the interval commencing on birthday x and applying it to V'_x, one obtains the number of probable deaths, which is equal to:

$$_aq_x \cdot V'_x$$

All these probable deaths will not be observed due to losses from observation E'_x. Assuming that such losses are spread uniformly over the interval and that they involve persons who are neither more nor less exposed to death than others, the number of deaths thus rendered unobservable may be estimated:

$$\tfrac{1}{2}\,{_aq_x} \cdot E'_x$$

Subtracting these unobservable deaths from probable deaths, one obtains observed deaths D'_x:

$$D'_x = ({_aq_x} \cdot V'_x) - (\tfrac{1}{2}\,{_aq_x} \cdot E'_x)$$

The death probability can thus be calculated using the following formula:

$$_aq_x = D'_x \,/\, (V'_x - \tfrac{1}{2}\,E'_x)$$

Probability $_aq_x$ may be calculated in this way when the three values D'_x, V'_x and E'_x are known.

To draw up a life table, the death probabilities that have been calculated are used to simulate the gradual extinction of a group of 1,000, 10,000 or 100,000 persons at birth in the manner discussed above. In this table, the number of survivors S(x) decreases only through the risk of death. The disruptive effect of losses from observation is thus completely eliminated.

It will be noted that eliminating this effect is based, in the final analysis, on the assumption that losses from observation were neither more nor less exposed to death than others. It would be well, therefore, to examine the likelihood of this assumption in every case, and especially when the number of losses from observation is relatively large.

D-02: • PROPORTION OF PERSONS EVER-MARRIED AT AGE 50
• TOTAL FIRST MARRIAGE RATE BEFORE AGE 50
• COMPLEMENT OF THE PROPORTION NEVER-MARRIED

I DESCRIPTION

Target Groups

All persons of the same sex born during a given year (birth cohort) or a given period (birth cohort group), provided that all survivors have reached or passed age 50.

Definition

Estimate of the proportion of persons in a birth cohort or birth cohort group who would ever marry for the first time, assuming that none of them are prevented from doing so by premature death.

Function

Among never-married persons who have died prematurely, some would have married if they had lived longer. The higher the death rate during childhood, adolescence or adulthood, the greater the number of persons in a given cohort who have never married. To make a valid comparison of the nuptiality of never-married persons from birth cohorts subject to very different mortality conditions, it is thus necessary to arrive at an assessment of this nuptiality that will be independent of the level of mortality. The three descriptors chosen for discussion here perform this function, since each of them provides a measure of the intensity of nuptiality obtained after eliminating the disruptive effects of mortality prior to age 50, after which first marriages are rare.

II COMMON USES

Eliminating the disruptive effect of mortality makes possible a valid comparison of the nuptiality of single persons belonging to cohorts born at widely varying times. Table 4 shows the observed and projected proportions of ever-married persons in a long series of Canadian birth cohort groups. It may be seen from this table that unions sanctioned by a marriage were very frequent in the past. Cohorts born in the first decades of the second half of the 19th century, however, married less frequently. Conversely, marriage became almost a general rule among cohorts born between the two world wars. The golden age of marriage was therefore in the rather recent past.

Long-term nuptiality trends show that Western populations first sought to control the birth rate by means of fewer marriages. In many countries, the frequency of never-married persons, as well as the average age at marriage, gradually increased until couples had attained a certain degree of control over their fertility. Then, slowly but surely, marriage became more frequent and took place earlier, as less children were born. It is as if some of the wisdom of earlier generations was being transmitted to us through changing patterns in first marriage rates.

Looking at table 4, the reader will certainly have noticed that the intensity of first marriages is measured for each sex separately. And yet, people cannot marry unless they find partners of the opposite sex. Ideally, the intensity of nuptiality should then be measured for both sexes together, but, in spite of much research, this unique descriptor has yet to be found. Demographers are thus obliged, for the time being at least, to continue to present one series of figures for women and another for men. They have, nevertheless, paid a great deal of attention to the effects of imbalances between the sexes on the marriage market. The study of specific situations and the development of models have thus demonstrated that short-term imbalances, such as those resulting from losses due to wars or from abrupt variations in the number of births, have little effect on the intensity of nuptiality, but a greater impact on the average age of first marriage and on age differences between spouses.

TABLE 4. Proportions Ever-married at Age 50, Canada, Birth Cohort Groups, 1826-30 to 1941-45

Birth cohort groups	Males	Females	Birth cohort groups	Males	Females
	percentage			percentage	
1826-1830	90.5		1886-1890	86.5	89.5
1831-1835	90.5	89.5	1891-1895	86.0	89.0
1836-1840	90.5	89.5	1896-1900	87.0	89.0
1841-1845	90.0	89.5	1901-1905	87.0	89.0
1846-1850	89.0	89.0	1906-1910	88.5	89.5
1851-1855	88.0	88.5	1911-1915	89.5	90.5
1856-1860	87.0	88.0	1916-1920	90.0	92.0
1861-1865	85.5	88.5	1921-1925	90.0	93.0
1866-1870	86.5	88.5	1926-1930	90.5	94.0
1871-1875	86.5	89.0	1931-1935	91.0	95.0
1876-1880	86.5	89.0	1936-1940	92.0	95.0
1881-1885	86.5	90.0	1941-1945		93.5

Source: Festy, P., "Canada, United States, Australia and New Zealand: Nuptiality Trends", **Population Studies**, XXVII(3), November 1973, p. 491.

III TECHNICAL DISCUSSION

Gross Nuptiality Table and Proportion Never-married

Leaving aside problems of observation, it can be said that the number of single persons in a birth cohort decreases with age due to first marriages and deaths of single persons. This decrease in numbers thus results from the combined action of two phenomena, only one of which will be discussed here. The gross nuptiality table is aimed specifically at showing what this decrease would be if nuptiality were the only phenomenon to act.

Looking at the example in Table 5, the reader may easily see that, in a table of this type, the number of single persons c(x) decreases from age to age only because of marriages m(x,x + 5); these marriage figures are obtained by multiplying c(x) by marriage probabilities ${}_5n_x$. It is then clear that the table enables one to follow the numerical decline in a group initially composed of 1,000 single persons and exposed until age 50 to the risk of marriage alone, or marriage probabilities. The situation presented involves single persons who remain under observation until their marriage or until the end of the period during which the nuptiality phenomenon is considered to manifest itself. For the group under study, the total number of marriages shown in the table represents all the possible occurrences of this phenomenon, and this enables one to calculate its intensity, or the "proportion of single persons who ever marry". This intensity, which is the complement of the proportion of never-married persons, is 93.6% in the example presented.

Because of the relationships existing between the three series of figures shown in the nuptiality table, all that needs to be known in order to compute the table is the series of marriage probabilities. Let us see how these probabilities are calculated.

The left-hand side of Table 5 shows the data collected by Charbonneau for a representative sample of the earliest female French-Canadian birth cohorts. First, the number (C_x) of single women still under observation at various birthdays x between the ages of 10 and 50 is given. For each age interval beginning at one of these birthdays, the first marriages (M_x) are given, as well as the number of deaths to single persons (D_x) and the number of losses from observation (E_x) due to emigration or deficiencies in the registration system. It may be seen that these are the only three sources of variation in the size of the group of single persons.

TABLE 5. Construction of a Gross Nuptiality Table for Canadian Female Birth Cohorts, 1640-1739

	Observed data					Gross nuptiality table		
Age x	Single persons C_x	Marriages M_x	Deaths D_x	Losses from observation E_x	$C_x - \frac{(D_x+E_x)}{2}$	Probability ${}_5n_x$ (per 1,000)	Single persons c_x (per 1,000)	First marriages $m(x, x+5)$
10	1,444	59	20	7	1,431	41	1,000	41
15	1,358	465	27	5	1,342	346	959	332
20	861	479	19	2	851	563	627	353
25	361	176	8	2	356	494	274	135
30	175	50	6	5	170	294	139	41
35	114	25	3	2	112	223	98	22
40	84	11	8	1	80	138	76	10
45	65	2	2	0	64	31	66	2
50	61						64	

Source: Charbonneau, H., **Vie et mort de nos ancêtres**, Montréal, Les Presses de l'Université de Montréal, 1975, p. 163.

Let ${}_5n_x$ be the risk of marrying within the next five years for a woman still single at birthday x. This is the risk that is to be calculated using the data collected. Applying this risk to the group C_x yields a number of probable marriages equal to:

$${}_5n_x \, . \, C_x$$

Some of these marriages will not be recorded due to deaths or losses from observation during the five years following birthday x. Assuming that these deaths and losses are distributed uniformly over the interval in question, and that the persons deceased or lost were neither more nor less exposed to marriage than the others, the number of marriages which were not observable can be estimated as:

$$\tfrac{1}{2}\left[({}_5n_x.D_x) + ({}_5n_x.E_x)\right]$$

Subtracting these unobservable marriages from the expected marriages, one obtains the marriages effectively observed and reported in the table:

$$M_x = {}_5n_x\left(C_x - \tfrac{1}{2}D_x - \tfrac{1}{2}E_x\right)$$

From this equation, the formula for calculating marriage probabilities can easily be derived:

$${}_5n_x = M_x/(C_x - \tfrac{1}{2}(D_x + E_x))$$

Proportions of Ever-married Persons

Another way of arriving at the intensity of first marriages is to direct our attention to those members of the birth cohort who have reached age 50, an age at which first marriages are sufficiently rare as to be negligible. Dividing the survivors at age 50 into never-married and ever-married enables one to calculate the proportion of persons ever-married at that age. This proportion measures the intensity of first marriages, since all persons under observation at that age have certainly completed all of that period of their lives during which this phenomenon may manifest itself.

As a general rule, single persons are less well counted by the census than are married persons, and their chances of survival are also poorer. The result is that the proportion of ever-married persons among census counts of persons of age 50 is normally higher than the intensity given in the gross nuptiality table for a given birth cohort. Such a proportion must consequently be considered an over-estimate of true intensity. This proportion has nevertheless been used in tracing

changes in nuptiality among Canadian birth cohorts, because the necessary statistics to develop a better descriptor are not available. It should be pointed out that this error in intensity should not be greater than 1 or 2 percentage points.

It is also common to calculate the proportion of ever-married persons among survivors at various ages below 50. The proportion of single persons, which is the complement of the first proportion, constitutes an estimate of the probability of not marrying before the age in question in the absence of any disruptive events, since it is calculated for a group of persons who have escaped such events. Thus, in a given cohort, the proportion of single persons among survivors at a given birthday is theoretically equal to the number of unmarried persons shown in the nuptiality table on that birthday, the only difference being that in this case the table is based on an initial cohort of 1,000 people. Based on this equality, the entire nuptiality table for that cohort can easily be deduced from the proportions single on various birthdays. In practice, however, this method would yield a slight over-estimation of the nuptiality of the cohort due to the census under-enumeration and the higher mortality experienced by single persons.

Total First Marriage Rate

As is the current practice in measuring fertility, one might also think of calculating "nuptiality rates" or "marriage frequencies". The number of first marriages observed between two birthdays is divided by the arithmetic mean of the size of the cohort on these birthdays, that is, the number of years lived by the members of the cohort between these two birthdays. Each rate would thus give the average number of first marriages per complete year lived between two consecutive birthdays. Summing these rates from the minimum age at marriage until the 50^{th} birthday would enable one to obtain the average number of first marriages per person for those who have completed the whole of the period during which nuptiality may occur. These total first marriage rates are thus a measurement of the intensity of nuptiality for the single persons of that cohort.

It is possible to show that this total first marriage rate is a slight under-estimate of the intensity of nuptiality, mainly because of the excess mortality of single persons.

D-03: MEAN AGE AT FIRST MARRIAGE

I DESCRIPTION

Target Groups

All persons of the same sex born during the same year (birth cohort) or the same period (birth cohort group), provided that those surviving have reached or passed age 50.

Definition

Age at which, on the average, members of a birth cohort or birth cohort group would marry if some of them were not prevented from doing so by premature death.

Function

By shortening the period during which certain persons are exposed to the risk of first marriage, mortality of single persons tends to shift the distribution by age of first marriages in a cohort towards the younger ages. The extent of this shift varies with mortality levels and is not the same from one cohort to another. In order to eliminate interference due to mortality the age-specific distribution of first marriages actually observed is substituted by that which would result from exposure of cohort members to the phenomenon of nuptiality alone. This new distribution, which is summarized by its average, or the mean age at first marriage, provides the true tempo of nuptiality of the single persons in a given cohort.

II COMMON USES

It is useful to consider together the tempo and intensity of nuptiality of the single. This is done in Table 6. The increase in intensity in the most recent cohorts has been accompanied by a lowering of the mean age. This is almost a general rule: the more people marry, the earlier they do so in their lives, and vice-versa. This age decrease has been more pronounced among men than among women.

III TECHNICAL DISCUSSION

It is not hard to see that the intrinsic characteristics of a demographic phenomenon can only be identified through the examination of situations in which persons remain exposed to it throughout that period of their lives during which the phenomenon is likely to manifest itself. This is why the analyst must offer measures of the nuptiality of single persons which are free from the interference that death can have on the period during which certain people are exposed to the risk of first marriage. This is done by using one of the three methods described in the technical discussion of the D-02 descriptors, i.e.: construction of a gross nuptiality table, use of the observed proportions of single persons among survivors at various birthdays, and calculation of marriage frequencies, or the average number of first marriages observed per year lived by the birth cohort in various age intervals.

Each of these three methods enables one to obtain an age-specific distribution of first marriages after eliminating the disruptive influence of deaths or losses from observation among the single. This provides the intrinsic tempo of nuptiality, which may be summarized as its average, or the "mean age at first marriage".

Since it is common to find differences in mortality according to marital status, the gross nuptiality table is to be preferred to the other two methods, which are mainly used when the statistics usually available are lacking.

TABLE 6. **Mean Age at First Marriage and Proportions Ever-married at Age 50 in Canada, Birth Cohort Groups, 1881-85 to 1941-45**

Birth cohort groups	Mean age at first marriage		Proportion ever-married at age 50	
	Males	Females	Males	Females
	years		percentage	
1881-1885	28.1		86.5	90.0
1886-1890	27.5	23.9	86.5	89.5
1891-1895	27.0	23.8	86.0	89.0
1896-1900	27.6	24.0	87.0	89.0
1901-1905	28.1	24.6	87.0	89.0
1906-1910	27.8	24.9	88.5	89.5
1911-1915	27.4	24.7	89.5	90.5
1916-1920	26.5	24.1	90.0	92.0
1921-1925	25.9	23.3	90.0	93.0
1926-1930	25.5	23.0	90.5	94.0
1931-1935	25.1	22.6	91.0	95.0
1936-1940	24.8	22.3	92.0	95.0
1941-1945		22.5		93.5

Source: Festy, P., op. cit., p. 491.

D-04: COMPLETED FERTILITY

I DESCRIPTION

Target Groups

Women who have reached the end of their childbearing period, distributed into groups according to year of birth (birth cohort) or year of marriage (marriage cohort).

Definition

Average number of live births per woman who has reached the end of her childbearing period.

Synonym

Lifetime fertility.

Function

The total number of births to a female cohort is diminished by the disappearance of some cohort members before their childbearing years are over. Other things being equal, the greater the rate of premature death, the greater the resulting decrease in total births. By definition, the index described here is free of this interference and consequently enables the fertility of cohorts subject to widely differing mortality conditions to be compared. It is the sum of live births throughout the childbearing period and constitutes a measure of the intensity of general fertility.

Looking only at legitimate fertility, one normally calculates the completed fertility of intact families, or the average number of live-born children produced by couples who were not separated by widowhood or divorce before the end of the women's childbearing years. This descriptor of the intensity of legitimate fertility is by definition free from interference by the diminishing effect of widowhood and divorce on the total live births produced by married couples.

II COMMON USES

Completed Fertility of Cohorts

(a) The first use of this descriptor is to show the basic trend of change over time in the general fertility of a population. To do this, chronological series are drawn up, such as that formulated by Henripin for Canadian cohorts born during the late 19th and early 20th centuries (Table 7).

To these estimates, which are very reliable since they deal with the fertility of cohorts whose fertility history is now complete, demographers often add other estimates of the completed fertility of cohorts whose fertility history is still incomplete. The fertility already achieved by these latter cohorts represents only a part of their completed fertility, although the closer they are to the end of their childbearing period, the closer this is to their ultimate total number of births. If this fraction were known, it would not be difficult to determine completed fertility from fertility to date. Since this is not the case, this figure must be estimated. The first method for doing this, which is a purely statistical one, consists of extrapolating the trend line of the appropriate fraction. This is how Collishaw estimated the probable completed fertility of the 1920-1938 cohorts from their cumulative fertility to date as of the 1971 census (Table 8). A second, rather more appealing, method consists in simply asking women still in their childbearing period how many more children they wish to have. If this figure is added to existing births for each woman, one obviously obtains their projected completed fertility. The use of the method, both in the United States and in Quebec, has been somewhat disappointing, however, since changing circumstances often lead women or couples to modify their plans.

TABLE 7. Estimates of Completed Fertility, Canada, Birth Cohort Groups, 1871-76 to 1916-21

Cohort group	Completed fertility[1]	Cohort group	Completed fertility[1]
1871-1876	4,118	1896-1901	3,444
1876-1881	4,067	1901-1906	3,138
1881-1886	4,007	1906-1911	2,944
1886-1891	3,891	1911-1916	2,943
1891-1896	3,714	1916-1921	3,120

[1] Per 1,000 women.
Source: Henripin, J., **Trends and Factors of Fertility in Canada**, Statistics Canada, Ottawa, 1972, p. 386.

TABLE 8. Estimates of Completed Fertility, Canada, Birth Cohorts, 1920-1938

Birth cohort	Completed fertility[1]	Birth cohort	Completed fertility[1]
1920	3,098	1930	3,273
1921	3,115	1931	3,239
1922	3,173	1932	3,217
1923	3,178	1933	3,239
1924	3,208	1934	3,185
1925	3,246	1935	3,127
1926	3,258	1936	3,078
1927	3,241	1937	3,020
1928	3,273	1938	2,954
1929	3,288		

[1] Per 1,000 women.
Source: Collishaw, N., **Fertility in Canada**, Catalogue 99-706, Statistics Canada, Ottawa, 1976, p. 66.

(b) Second common use: historical changes in the completed fertility of cohorts are commonly used to assist in interpreting variations over time in the "total fertility rate", this rate being without a doubt the most important period descriptor of fertility (see presentation of this descriptor in Chapter 4).

Completed Fertility of Marriage Cohorts

The fertility of married couples, or legitimate fertility, is by far the most important component of general fertility, and thus deserves particular attention. To calculate the completed fertility of married women, one can group the appropriate women by either the year of their birth or that of their marriage. Experience has shown that the latter approach is preferable, if only because it groups women whose married lives has evolved over the same period in time. As long as most human reproduction takes place within marriage, the completed fertility of marriage cohorts will remain a major descriptor of fertility.

In Canada, however, currently available statistics do not permit this calculation. A related descriptor must be substituted, that is, "completed fertility of ever-married women by date of first marriage". Information obtained from a sample of Canadian women during the 1961 census enabled Légaré to prepare the estimates shown in Table 9. Leaving aside the figures in parenthesis, this table gives a fairly accurate picture of changes in average family size for women belonging to various first-marriage cohort groups. Some of these families, however, are not intact due to death of

the husband or divorce before the end of the childbearing period, while others, and sometimes the same ones, include children born before the first marriage or following a remarriage. This is why, strictly speaking, this descriptor of completed fertility of ever-married women must not be confused with the completed fertility of intact first marriages, even if the former probably provides a good estimate of the latter.

TABLE 9. Completed Fertility of Ever-married Women by Period of First Marriage, Canada, 1910-14 to 1940-44

Marriage cohorts	Age at first marriage		
	All ages	Less than 22 years	22-44 years
1910-1914	(4.46)	5.50	(3.72)
1915-1919	(4.11)	5.11	(3.27)
1920-1924	3.76	4.62	2.96
1925-1929	3.55	4.32	2.80
1930-1934	3.42	4.18	2.78
1935-1939	3.29	4.08	2.75
1940-1944	3.14	3.72	2.67

Source: Légaré, J., "Demographic Highlights on Fertility Decline in Canadian Marriage Cohorts", **Canadian Review of Sociology and Anthropology**, 11, 4, 1974, p. 293.

Even if the concept of completed fertility of marriages is hardly used in official Canadian publications due to the lack of appropriate statistics, it is quite commonly used in specialized surveys. An example would be the study by Henripin and his colleagues on the fertility of Quebec women, from which have been taken the results shown in Table 10.

III TECHNICAL DISCUSSION

Direct Calculation

The easiest way to determine the completed fertility of women who have reached or passed age 50 is to ask them. This was done during the Canadian censuses of 1941, 1961, 1971 and 1981. For reasons that are easy to imagine, however, only women who have ever been married are normally questioned about the number of children they have had. To obtain the completed fertility of all women, it is necessary to proceed as follows:

TABLE 10. Expected Completed Fertility, Quebec, Marriage Cohort Groups, 1946-50 to 1966-71

Marriage cohorts	From 1971 Survey	From 1976 Survey
1946-1950	3.86	
1951-1955	3.42	4.51
1956-1960	3.05	3.20
1961-1965	2.86	2.55
1966-1971	2.83	2.38

Source: Henripin, J., Huot, P.-M., Lapierre-Adamcyk, E., Marcil-Gratton, N., **Les enfants qu'on n'a plus au Québec**, Montréal, P.U.M., 1981, p. 27.

(a) Multiply the completed fertility of ever-married women by their proportion among the surviving members of their birth cohort. This gives the completed fertility of the cohort, assuming the surviving single persons had no children.

(b) Divide this first estimate of the completed fertility of the birth cohort by an estimate of the proportion of births to ever-married women out of the total number of births. As a result the completed fertility of never-married women is included in this final figure.

As an example, there follows the calculation for Canadian women aged 50-54 at the time of the 1961 census:

Completed fertility of ever-married women	3,188
Proportion of women ever married	0.896
Product: (3,188) x (0.896) =	2,856
Proportion of legitimate births	0.970
Quotient: (2,856/0.970) =	2,944

The completed fertility of Canadian women born between June 1, 1906 and May 31, 1911, is thus estimated at 2,944 children[3] per 1,000 women.

Indirect Calculation

Let us assume that a cohort of women produced 150 live births between the 15th and 16th birthdays of its members, and that the number of members who were alive at their 15th birthday was 75,000. Calculating the ratio of these two figures, one obtains the general fertility rate at age 15: 150/75,000 = 0.002, or 2 per 1,000. This rate is the average number of live births per year lived between the birthdays in question, since the number of members of the cohort whose age at last birthday is 15 is equal to the total number of years lived by its members between their 15th and 16th birthdays.

Assuming that it is possible to repeat this calculation for all ages included in a woman's reproductive period, the series of general fertility rates will give the series of average numbers of live births per year lived in the annual intervals bounded by consecutive birthdays. Since all survivors at the end of the childbearing period live one year in each of these annual intervals, one can estimate the completed fertility of the birth cohort by the sum of the general fertility rates.

The completed fertility of a birth cohort may thus be obtained by first calculating the general fertility rates for each age, then adding up these rates for all ages included in a woman's reproductive period.

The completed fertility of a marriage cohort may be calculated by using a procedure formally identical to the above: (a) calculating legitimate fertility rates for each year of marriage by taking as the denominator the number of couples still intact at each duration interval, and (b) adding together these rates up to 20 or 25 years of marriage. It would be preferable to make this calculation by age group at marriage if it is felt that there will be a gradual change in the initial composition of the cohort due to divorce or widowhood.

Comparison of the Two Calculations

The direct method of calculation is based on the results of a retrospective survey of women who have reached or passed the end of their childbearing years. When asked the total number of live births they have had, some women will leave out one or more children who died very young. In addition, the fertility of women who can be thus questioned is not necessarily representative of that of their birth or marriage cohort. It could, for example, be imagined that these survivors enjoyed

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[3] Henripin, J., **Trends and factors...**, **op. cit.**, p. 386.

good health, which gave them a greater fertility than their deceased contemporaries had, or, on the other hand, that the risk of death related to childbearing lessened the chances of survival of more fertile women. Migration may also have a similar selective effect.

The indirect method of calculation is less susceptible to these effects of selectivity. The calculation of fertility rates allows one to include at each age the fertility of all women still alive and present in the group. Thus, a woman who has died or emigrated before the end of the reproductive period will be included in the denominator of all rates calculated up to her death or departure, while any children born to her before death or emigration will also be included in the appropriate numerators. In the same way, for a woman who immigrates, only her fertility level after her arrival will be taken into account. In this way, the sum of the age-specific (or marriage-duration specific) fertility rates has a better chance of yielding a more representative estimate of the completed fertility for the birth or marriage cohort.

It should be noted that, for Canada, the indirect method of calculation yields estimates of completed fertility that are slightly lower than those obtained by the direct method.

D-05: MEAN AGE AT CHILDBIRTH

I DESCRIPTION

Target Groups

Women born during the same year (birth cohort) or during the same period (birth cohort group), provided that all surviving members of the cohort have reached or passed the maximum age for childbearing.

Definition

Mean age of childbearing for women who have completed their reproductive period.

Synonym

Mean age of fertility, mean age of mothers.

Function

In a female birth cohort, the number of children born at a given age depends on both the number and the fertility of survivors at that age. Consequently, the actual distribution of children born by age of mothers gives an imperfect picture of age-specific variations in fertility, since this fertility is also influenced by the gradual reduction in the number of survivors during the childbearing period. This makes it necessary to replace this actual distribution by a distribution exempt from interference by mortality, especially since this interference is not the same from one cohort to another. As opposed to the first distribution, the second one gives a faithful description of age-specific variations in fertility, and its mean is a good descriptor of the tempo of general fertility.

II COMMON USES

(a) The historical variation in the mean age at childbirth is often compared to that of completed fertility. This comparison for a number of Canadian birth cohorts bears witness to the differences in their evolution (Table 11).

(b) Mean age at childbirth is also used as an aid in interpreting the total fertility rate (see Chapter 4).

III TECHNICAL DISCUSSION

Direct Calculation

By asking women who have reached the end of the childbearing period how old they were at the birth of each of their children, one can collect all the information necessary to calculate the mean age at childbirth as described above. Unfortunately, this information is not available for Canadian birth cohorts.

Indirect Calculation

Following a female birth cohort throughout its childbearing period, it is possible to record the number of live births occurring between successive birthdays. At each age, the number of live births can be divided by the size of the cohort to obtain the general fertility rate. This produces a total of 35 fertility rates, which would give the average number of live births per year lived in each of the annual intervals making up the reproductive period.

TABLE 11. Completed Fertility and Mean Age at Childbirth, Canada, Cohorts Born from 1901 to 1930

Birth cohort	Completed fertility[1]	Mean age of fertility	Birth cohort	Completed fertility[1]	Mean age of fertility
1901	3,14	29.02	1916	2.92	29.64
1902	3,08	29.05	1917	2.96	29.59
1903	3.04	29.08	1918	3.02	29.50
1904	2.98	29.16	1919	3.08	29.37
1905	2.93	29.22	1920	3.13	29.28
1906	2.90	29.26	1921	3.18	29.14
1907	2.87	29.30	1922	3.24	28.98
1908	2.83	29.41	1923	3.27	28.80
1909	2.82	29.49	1924	3.29	28.60
1910	2.79	29.55	1925	3.31	28.43
1911	2.77	29.67	1926	3.30	28.33
1912	2.78	29.73	1927	3.31	28.17
1913	2.80	29.82	1928	3.32	27.90
1914	2.84	29.75	1929	3.33	27.68
1915	2.88	29.71	1930	3.35	27.42

[1] Average number of children per woman.

Source: Vanasse-Duhamel, D., "Translation Models as an Aid to the Analysis and Projection of Fertility in Canada", in **Technical Report on Population Projections for Canada and the Provinces 1972-2001**, Catalogue 91-516, Statistics Canada, Ottawa, 1975, p. 72.

Women still alive at age 50 have necessarily lived one complete year in each of the annual intervals mentioned. As a result, the average number of children born to them between two successive birthdays is given by the general fertility rate corresponding to that age. The mean age at childbirth would then be calculated, like any mean, in the following manner: first multiply the fertility rate at each age x by $(x+0.5)$, then add together the products calculated for all ages x, and then divide this sum of products by the sum of the fertility rates or completed fertility.

D-06: GROSS REPRODUCTION RATE

I DESCRIPTION

Target Groups

All women born during the same year (birth cohort) or during the same period (birth cohort group), provided that the survivors, if any, have reached or passed the maximum age of childbearing.

Definition

Average number of girls born to women who have completed their reproductive period.

Synonym

Completed fertility or lifetime fertility, measured in terms of the number of daughters.

Function

See "D-04: Completed fertility".

II COMMON USES

See "D-07: Net reproduction rate".

III TECHNICAL DISCUSSION

Calculated by multiplying the completed fertility of the birth cohort by the proportion of total births that were female births, i.e. 0.488.

D-07: NET REPRODUCTION RATE

I DESCRIPTION

Target Groups

Women born during a given year (female birth cohort) or during a given period (female birth cohort group), provided that these women have reached the end of their childbearing period.

Definition

Ratio of the number of daughters produced by a given female birth cohort to the original number of women in the cohort.

Synonym

Net completed fertility or net lifetime fertility, measured in terms of the number of daughters.

Function

The net reproduction rate is calculated by comparing two female groups at birth: that of daughters and that of the birth cohort of their mothers. The calculation is aimed at estimating to what degree a female birth cohort ensures its own replacement.

Similar Descriptors

Instead of comparing the size of groups at birth, one could compare the number of daughters surviving at age x, to the number of survivors at the same age in the birth cohort of mothers. One would thus obtain the "net reproduction rate at age x", which is generally different from the net reproduction rate at birth. The estimate that is made of the replacement of a cohort thus depends on the age chosen for the calculation. This has led to the idea of computing a "net reproduction rate in terms of the total number of years lived", which would provide an overall estimate of the replacement of a birth cohort. All these descriptors will be discussed in the section that follows below.

It should also be mentioned here that the net reproduction rate for male birth cohorts can also be calculated, but is only rarely used.

II COMMON USES

As its definition clearly shows, the net reproduction rate indicates whether a female birth cohort has been able to ensure its replacement in terms of the number of daughters produced by its members. The examination of a chronological series of these rates yields much valuable information on the natural replacement of the birth cohorts making up a population. Thus, in the absence of migration, an uninterrupted series of rates higher than one indicates the formation of larger and larger birth cohorts, while an uninterrupted series of rates lower than one suggests a gradual decrease in the initial size of successive birth cohorts.

It must, however, be borne in mind that any estimate of the net reproduction rate of a cohort depends on the age considered. A decline in mortality over the centuries has led to better overall chances of survival for daughters than for their mothers, and the ratio between the survivors of these two groups thus increases with age. In particular, it may happen that a given cohort is unable to ensure its replacement at birth, although it may be able to do so in adulthood or old age, as may be clearly seen from the net reproduction rates calculated at various ages[4] for selected French birth cohort groups (Table 12).

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[4] The net reproduction rate at age x is the ratio between the number of daughters surviving at that age and the number of survivors at the same age in the birth cohort of their mothers.

TABLE 12. Various Measures of Reproduction, France, Birth Cohort Groups, 1826-30 to 1846-50

Birth cohorts	Net reproduction			Reproduction rate in terms of the total number of years lived
	At age 0	At age 15	At age 60	
1826-1830	0.95	0.98	1.06	0.98
1831-1835	0.94	0.98	1.07	0.98
1836-1840	0.97	0.99	1.09	1.03
1841-1845	0.98	1.00	1.11	1.07
1846-1850	0.97	1.01	1.14	1.10

Source: Depoid, P., **Reproduction nette en Europe depuis l'origine des statistiques de l'état civil.** Paris, 1941, quoted in Pressat, R., **L'analyse démographique** (2nd Edition), Paris, P.U.F., 1969, pp. 248 and 251.

This suggests that a population may continue to experience natural growth even though cohorts may fail to ensure their replacement in terms of the numbers at birth.

It is a known fact that prolonging the duration of schooling causes the school population to increase, even when the number of new students admitted each year does not vary. In the same way, the total population may increase simply due to an increase in mean length of life. In the absence of migration, the total contribution of a birth cohort to the size of a population depends on the initial number of its members and on how long they live, and is thus best measured by the total number of years lived by its members. This is what gave rise to the idea of comparing the number of years lived by daughters to those lived by the birth cohort of their mothers. If this ratio, or "reproduction rate in terms of the total number of years lived" is greater than one, natural increase of the population is ensured, while if it is less than one this is not the case.

III TECHNICAL DISCUSSION

Current vital statistics do not lend themselves to direct calculation of the net reproduction rate. These statistics, drawn from records of vital events occurring each year within a given territory, obviously cannot include births to women who have emigrated to other areas, and thus the numerator of the net rate cannot be calculated.

The net reproduction rate is accordingly calculated by an indirect method. Multiplying the completed fertility of the cohort by the proportion of females at birth (0.488) gives the completed fertility (expressed in number of daughters), or the gross reproduction rate. This gross rate is a measure of reproduction assuming no mortality before age 50 in the birth cohort of mothers. To go from the gross to the net rate, the diminishing effect of mortality which precedes potential births must be introduced; this is done by multiplying the gross reproduction rate by the survival rate of the cohort at the mean age at childbirth. Work in mathematical demography has shown that, if only 80% of women survive to the mean age of childbearing, the number of daughters they will bear will be 20% less than in the absence of any mortality before the end of the childbearing period.

Calculation of the net reproduction rate thus presupposes knowledge of the series of age-specific general fertility rates (summarized by completed fertility and mean age at childbirth), as well as of the life table, from which is obtained the survival rate for the mean age at childbirth.

CHAPTER 3

DESCRIPTORS OF THE STATE OF THE POPULATION

Censuses give the most detailed and complete information on the state of the population at given points in time. In Canada, censuses are carried out in June in all years ending in 1 or 6. Between censuses, the state of the population is determined through surveys and population estimates based on information from vital statistics and migration statistics.

Of all the information available, only that which deals with demographic structures per se will be considered here: distributions by age and sex, marital and family status. These structures are the product of past changes in demographic phenomena and, in turn, influence demographic change in the short and medium term.

D-08: AGE PYRAMID

I DESCRIPTION

Definition

The age (or population) pyramid is a double histogram which shows the age and sex composition of a population on a given date and which is "so named because of its pyramidal shape".[1]

Functions

Like all histograms, the population pyramid enables one to see at a glance a statistical distribution which is easier to appreciate in its graphic representation than through the underlying table. In particular, any imbalances in age composition or sex distribution can easily be seen through the representation of these values by bars of varying lengths.

Since major upsets in the demographic situation of a country show up as sharp variations in the size at birth of successive cohorts or, occasionally, as major changes in sex ratios in adulthood, the population pyramid, which preserves the effects of such variations over long periods of time, is the quickest way to trace these disruptions. It might be said that it gives the broad outline, in a kind of photographic image, of changes in the population over more than half a century.

For instance, the juxtaposition of population pyramids drawn up at various dates illustrates the aging of Western populations.

II INTERPRETATION

Population Pyramid and Demographic History[2]

Figure 2 shows clearly the age structure of Canada's population for both sexes.

The general triangular form of the population pyramid shown in the chart is due mainly to mortality, which progressively reduces the size of successive age categories. In addition to age, there is also the cohort factor: individuals born in the same year become subject to events unique to them, and these events may have affected the age structure of June 3, 1981. By presenting data by single years of age as a pyramid, an overview of the history of the Canadian population since the turn of the century is obtained.

Starting with the peak of the pyramid, a few of the events that have influenced the shape of the pyramid for both males and females will be noted. The first irregularity in shape occurs for persons born in the 1915-1919 period, and this indentation is the result of the deficit of births during the First World War. The second indentation, which affects a larger number of years of age, is caused by three factors: the drop in fertility during the Depression of the 1930s[3] (i.e. postponed marriages and voluntary infertility), the fact that the 1915-1919 cohorts, themselves small, were in their reproductive period, and the disturbing effect of the 1939-45 war (i.e. absent spouses and postponed marriages). Beginning in 1946, there was a recovery in births[4] which had been postponed by the Second World War, and then a substantial increase in natality which has been called the

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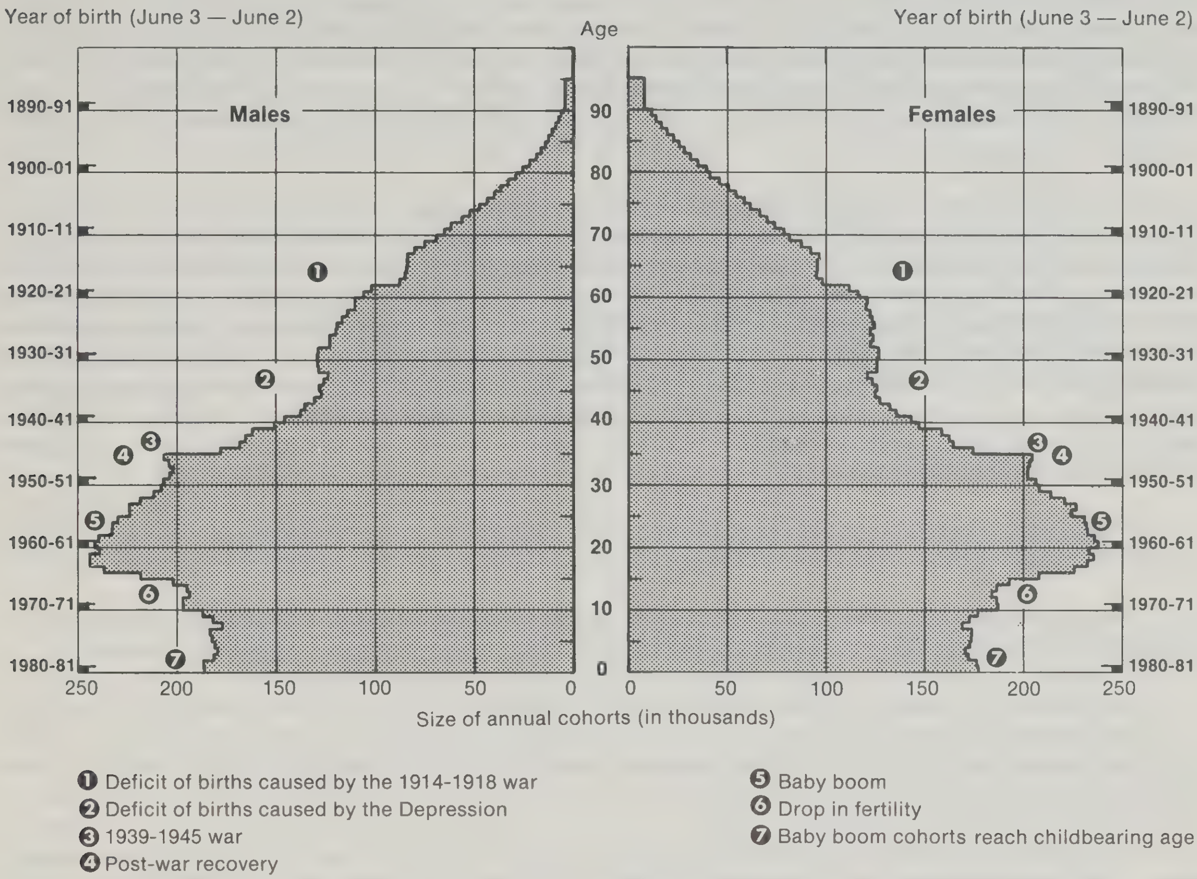
1 Van de Walle, E., **Multilingual Demographic Dictionary** (English section, 2nd ed.), Liège, Ordina, 1982, p. 47.

2 This passage is taken, almost in its entirety, from Statistics Canada, **Estimates of Population by Sex and Age for Canada and the Provinces, June 1, 1977,** Catalogue 91-202, Statistics Canada, Ottawa, November 1978, pp. 13-15.

3 Actually, the decline in the number of births had begun prior to the Depression, falling from a level of 256,875 in 1921-22, and not reaching this level again until 1941-42, at which time there were 260,962 births in Canada. See Fleming, M., **Births, Deaths and Immigration on a Census-year Basis for Canada and the Provinces, 1921 - (Immigration 1931) - 1966,** Technical Memorandum (General Series), No. 14, Population Estimates and Projections, Census Division, Dominion Bureau of Statistics, Ottawa, January 20, 1967, Table 2.

4 This is evident from the substantial increase in the number of births, which went from 298,776 in 1945-46 to 354,345 the following census-year. See Fleming, M., **op. cit.,** Table 2.

Figure 2
Population Pyramid, Canada, June 3, 1981



Source: Statistics Canada, 1981 Census of Canada.

baby boom. This accounts for the bulge in the pyramid up to around 1960. The following indentation in the pyramid is caused by the recent drop in natality, which has been particularly marked since 1965, and by the reduced number of women of childbearing age, who had been born during the Depression or the Second World War. It should also be mentioned that the baby boom cohorts are reaching their reproductive period: if there is no significant change in couples' reproductive behaviour, there will be an increase in the number of births in the next few years, and hence a broadening of the base of the pyramid (which is already apparent).

Aging of Populations

Comparison of pyramids drawn up over the past century or so for the populations of industrialized countries reveals an almost universal aging phenomenon. This aging of populations, which must be distinguished from individual aging, or senescence, is "a progressive change in the age distribution of a population which produces an increasingly greater proportion at older ages and, as a correlate, an increasingly smaller share at younger ages".[5] This aging is clearly illustrated by the changes in the age distribution of the French population between 1776 and 1951, due to the very early and pronounced nature of its manifestations in that country (Figure 3).

Tracing the chronological progression of aging in Western populations reveals the demographic process which engendered and maintained it. By 1870, 12% of the French population was already over 60, while this percentage was reached only 40 years later in Sweden and 60 years

[5] Translated from Pressat, R., **Dictionnaire de démographie,** Paris, P.U.F., 1979, p. 282.

later in England. It should be emphasized that this earlier aging in France took place in spite of the fact that its mortality did not decrease any earlier or any more sharply than in the other two countries. The fact is that France also showed a similar lead over other countries with respect to the onset of the drop in natality. As a general rule, an increase in the proportion of older persons occurs along with a decline in natality and normally begins several decades after the start of a decline in mortality. It is thus clear that the aging process observed up until now is basically the result of a progressive shrinking of the size of new birth cohorts. In fact, the upswing in natality in the post-war period was sufficient in certain countries to spark off the opposite phenomenon: that of the population becoming younger.

Contrary to what has often been stated, increasing longevity has played only a minor role in the aging of populations. Of course, as was seen in discussing the net reproduction rate, this increase in longevity causes the ratio between the birth cohorts of children and that of their parents to increase with age, but this aging effect remains a very secondary factor compared to that produced by the gradual decrease in births. Conversely, the fact that aging in the female population is more marked today than in the male population of the same country can only be explained by women's better chances of survival. The lead taken by women in this area foreshadows the new situation that would result from an improvement in human longevity due to a lengthening of time spent in old age. Aging at the base of the pyramid, which has been the rule up until now, would then be replaced by aging at the apex.

Migration, when it involves large numbers moving in the same direction, modifies the rate of population aging. Emigration causes it to speed up, while immigration causes it to slow down.

The pyramids in Figures 3 and 4, drawn to the same scale, allow one to observe the later start of aging in the Canadian population than in France and its less advanced stage of development.

As opposed to France, which has probably had a longer tradition of limitation in births than any other country in the world, Canada ranked until quite recently among the developed countries with the highest fertility, and benefited from relatively strong immigration, which is another factor producing a younger population.

The French population has thus become a typical example of aging, while Canada is still among the industrialized countries having the youngest age structure: in 1981, 9.7% of the population was over 65, while France had already exceeded that proportion in 1936.

III TECHNICAL DISCUSSION

Data Required

To draw up a population pyramid, it is obvious that a fairly detailed breakdown by age for persons of each sex is needed.

Normally, individuals are classified as to the last birthday they have reached, that is, the number of complete years they have lived. All persons whose exact age at the moment of observation is equal to or greater than x, but less than x + 1, will be included in the age group "x complete years". By the same principle, all persons belonging to the group "x, x + 4" are those whose true age at the time of observation was equal to or greater than x years exactly, but less than x + 5 years exactly.

More rarely, individuals are listed according to the age they reached during the calendar year in which the state of the population was drawn up. This is the same thing as classifying them as to year of birth. The results would be the same as in the previous classification if the date of observation were January 1st. On other dates, age groups are not bounded by birthdays, since the true age of members of a birth cohort at a given point in the year falls into a one-year interval straddling their birthday. The precise limits of this interval must then be determined using a Lexis diagram and expressed in years and tenths of years. Since this is a fairly rare situation, this problem will not be discussed here; readers requiring further information should consult standard demography manuals.

Construction of a Pyramid

The basic rule in drawing up this pyramid is that, for each sex, the size of an age group, or the proportion which corresponds to it, must be represented by the area of a rectangle. Consequently, the vertical side of this rectangle must be proportional to the number of years contained in the age interval, and the horizontal side must be proportional to the mean size or the mean proportion per year of age within the age group. For the reason mentioned above, if this rule were not respected, the pyramid obtained would provide a deformed picture of the age-specific distribution of the population and would give rise to errors of interpretation.

Examination of an existing pyramid will help to understand how the rectangles, or bars, are organized. First, there are two vertical half-axes, fairly close together, beginning at two points located on either side of the midpoint of a straight horizontal line. These vertical half-axes are each marked off in the same arithmetic scale of ages, made up of small segments of a length proportional to the size of the age intervals adopted. On the horizontal line, there are two arithmetic scales, going in opposite directions, on which are measured the mean size of the group or the mean proportion by year of age; the left-hand scale is for males, and the right-hand one for females. These are the ordinates and abscissas needed to draw all the bars.

In order to arrive at an appropriately formed pyramid, the scales chosen should be such that the maximum height is equal to 2/3 of the width of the pyramid.

Calculations

The population pyramid may be calculated either from the numbers of each sex by year of age or by age group, or from the proportions these groups constitute of the total population, i.e. the total of all ages and both sexes. Calculating these proportions, or class frequencies, is obviously the best method when the pyramid is to be compared to that of a population of an entirely different size.

When using a breakdown by age group, the mean size of each single year of age within the various age groups should be calculated. Since, other things being equal, the size of an age group depends on the number of years included in the group, such a calculation is necessary to obtain the true picture of the distribution by age. This eliminates differences due to the unequal size of age intervals which may be encountered in the base statistics. The same would apply to class frequencies: one would thus calculate, for each age group, the proportion that its mean size per single year of age represents in the total population. These mean figures or proportions per year of age will then be used to draw up the pyramid.

If the last age group is an open group, e.g. "85 years and over", the size of the group must first be broken down into the smaller age groups of which it is composed. This breakdown might be made using more detailed statistics on a population judged to be similar. The inevitable arbitrariness of such a procedure normally does not affect the quality of the graphic representation as a whole.

Dependency Ratio

The analysis of age structure usually includes some reference to the relative size of broad age groups: for instance 0-14 years (children), 15-64 years (adults), and 65 years and over (the elderly). The percentage distribution among these groups indicates the stage reached by the population in the aging process. In addition, the age dependency ratio gives an indication of the relative importance of the so-called dependent population, while the aged-to-child ratio shows the composition of this dependent population.[6]

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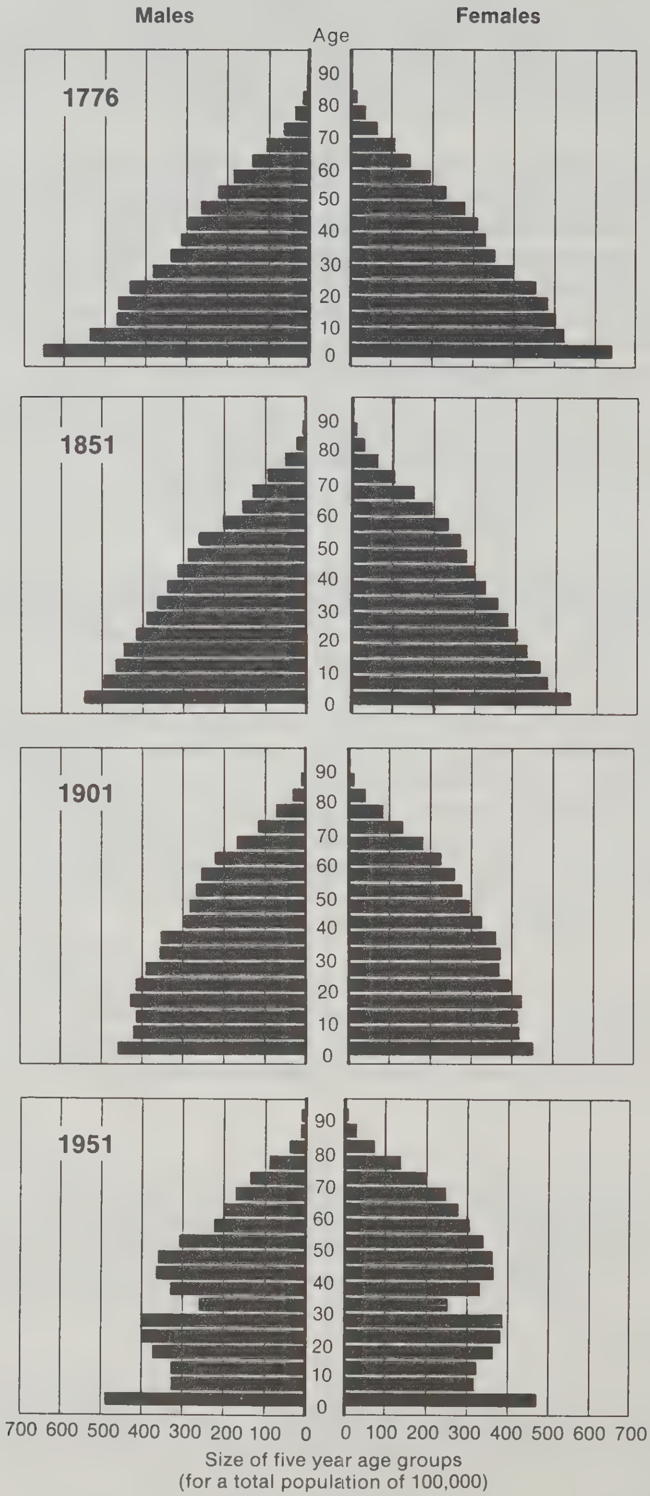
6 For an example of how these ratios are used, see Statistics Canada, **Estimates of Population..., op. cit.**, pp. 15-16, and Norland, J.A., **The Age-Sex Structure of Canada's Population** (Profile Study, 1971 Census of Canada), Catalogue 99-703, Statistics Canada, Ottawa, 1976, pp. 21-53.

Figure 3

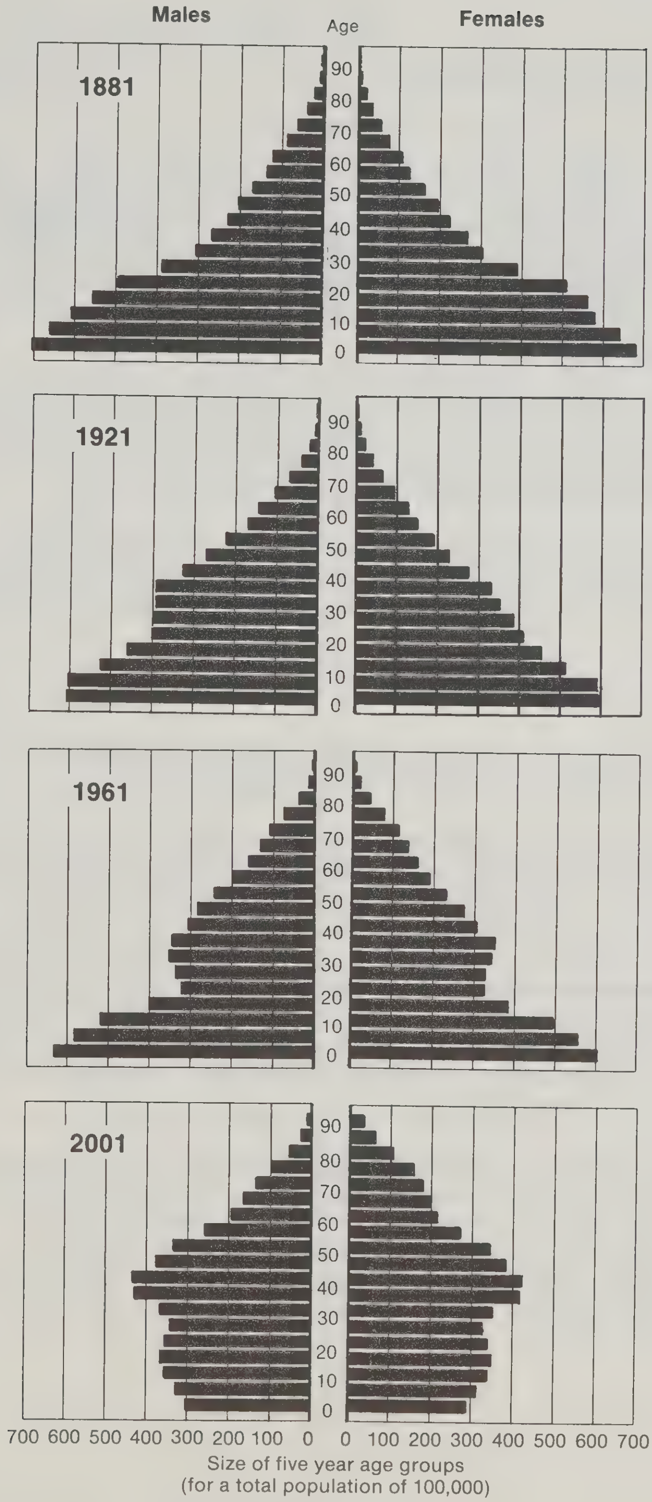
Changes in Age Structure, France, 1776-1951



Source: Bourgeois-Pichat, J., "Évolution de la population française depuis le XVIII[e] siècle", Population, 4, 1951, pp. 661-662; I.N.S.E.E., Statistique du mouvement de la population, 1950 et 1951, Paris, P.U.F., 1956, pp. 22-23.

Figure 4

Changes in Age Structure, Canada, 1881-2001



Source: Statistics Canada, 1881, 1921 and 1961 Censuses of Canada, and projection 4 (catalogue 91-520)

D-09: SEX RATIO

I DESCRIPTION

Definition

Number of males per 100 females.

Functions

The sex ratio at birth provides an indication of the quality of registration of live births. When these births are sufficiently numerous and registration is complete, this ratio is very close to 105. Higher figures have occasionally been observed just before or just after the end of a war, both in the countries at war and in neutral countries. To date, no generally accepted theory has been able to explain the existence of this biological constant in human reproduction, nor the origin of the short-term deviations that have been observed.

Sex ratios normally decrease with age due to excess male mortality.Thus the excess of males recorded at birth is gradually eroded in favour of an increasingly important excess of females in adult ages. Age-specific changes in these ratios thus give a clear picture of differences in aging by sex, and they also illustrate the underlying cause of these differences.

The comparison of observed data with this expected standard pattern of age-related changes in imbalance between the sexes, enables one to identify certain weaknesses in population censuses and reveals the impact of wars and migration on the sex composition of certain age groups.

II INTERPRETATION

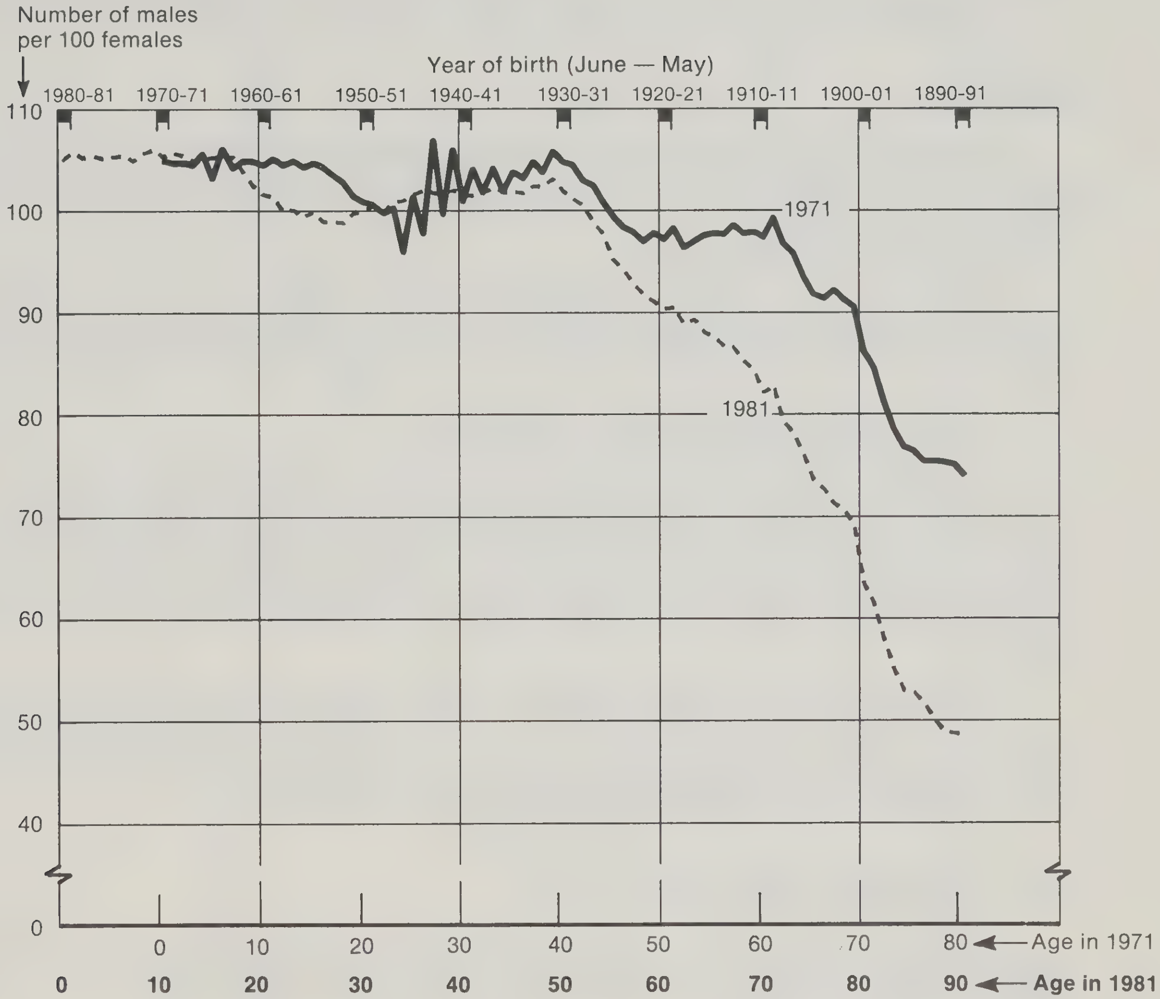
Figure 5 gives an even clearer picture than the population pyramid of disproportions in numbers of males and females at various ages in the population.

As in the case of the population pyramid, in order to analyse changes in the sex ratio, a distinction is made between the age effect and the cohort effect. The impact of the age effect can be summarized as follows: approximately 105 boys are born for every 100 girls, but because of the excess mortality among males, this ratio decreases as age increases, particularly after age 45, thereby producing the general shape of the curve. The cohort effect changes the curve that would result from mortality alone. This is because each cohort is unique and experiences events which serve to alter the sex ratio that would result from the age effect acting alone. For example, some variations in the excess mortality of males are caused by wars. In addition, changes in health conditions or lifestyle have affected the mortality of one sex more than the other, just as migration may affect one sex more than another.

Some irregularities in the curve in Figure 5 are, however, not due to age or cohort effects, but are rather an indication of the quality of the census from which these data are taken. The dip observed around age 25 is an example of this; it probably results from a more pronounced undercoverage of males, due in turn to their high mobility at these ages. The fact that dips in the curve are found at the same age in 1971 and 1981 seems to confirm this interpretation. Census deficiencies are also responsible for the saw-tooth shape of the 1971 curve between ages 25 and 30.

Figure 5

Sex Ratio by Age, Canada, 1971 and 1981



Source: Statistics Canada, 1971 and 1981 Censuses of Canada.

D-10: DESCRIPTORS OF MARITAL STATUS

I DESCRIPTION

Definition

Distribution of persons by marital status, whether de facto or de jure, at the time of observation.

Functions

The marital status of individuals on a given date tells whether they have ever entered into a conjugal relationship and if they continue to be so engaged. The distribution of persons by marital status provides an indication of the extent to which individuals live as couples, and the frequency with which these unions are dissolved.

This distribution naturally varies with age, and depends on the past development and interplay of several demographic phenomena: nuptiality (including remarriage), divorce and widowhood. It tells more about the nuptiality of single persons than about divorce or widowhood.

II INTERPRETATION

Figure 6 illustrates the variations in the proportion of single persons at various ages between 1971 and 1981. It may be seen that more recent birth cohorts married less frequently at the younger ages than did their predecessors. The difference would be even greater if common-law unions had not been taken into account. In 1981 approximately 15% of single men aged 20-29 and 20% of single women of the same age cohabitated without being married. These have been counted as married in the census.

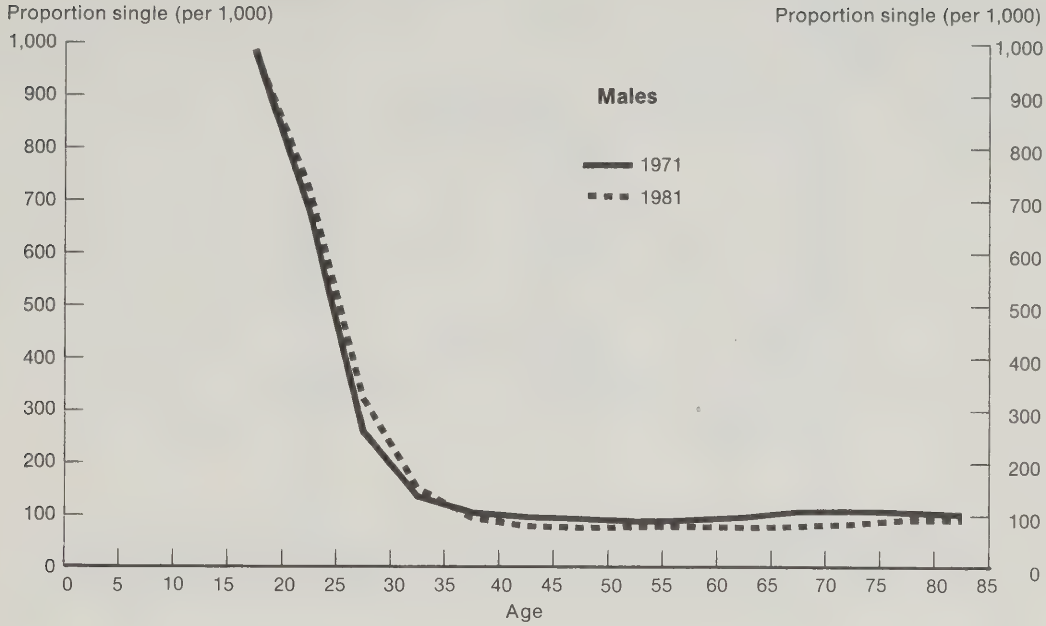
Figure 7 shows changes between 1971 and 1981 in the proportion of persons divorced among those ever-married. This proportion has increased considerably for both sexes, but to a greater degree for women than for men. This anomaly may be explained by the fact that divorced men remarry more frequently and more quickly than do divorced women.

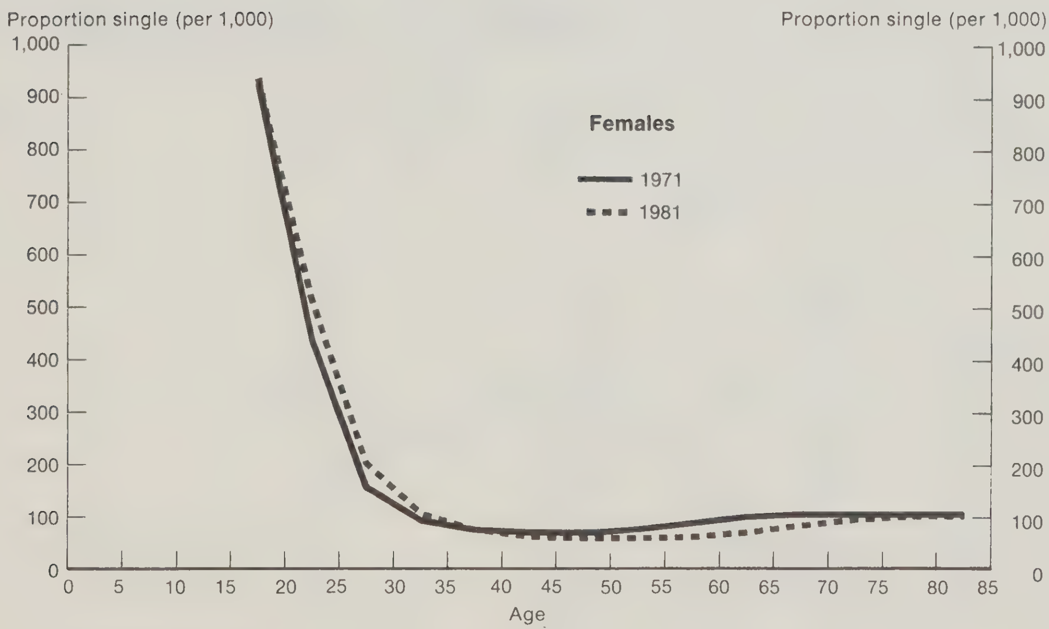
III TECHNICAL DISCUSSION

In the Canadian censuses of 1971, 1976 and 1981, persons living in common-law unions were asked to report themselves as married, regardless of their legal marital status. Distributions computed from these censuses are therefore based on **de facto** marital status.

Figure 6

Proportion Single by Sex and Five-year Age Groups, Canada, 1971 and 1981

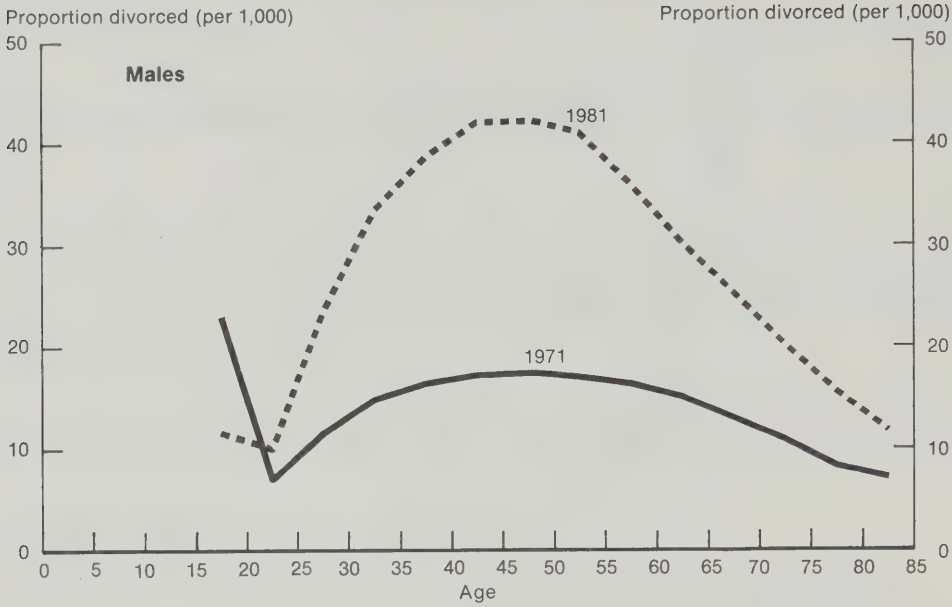


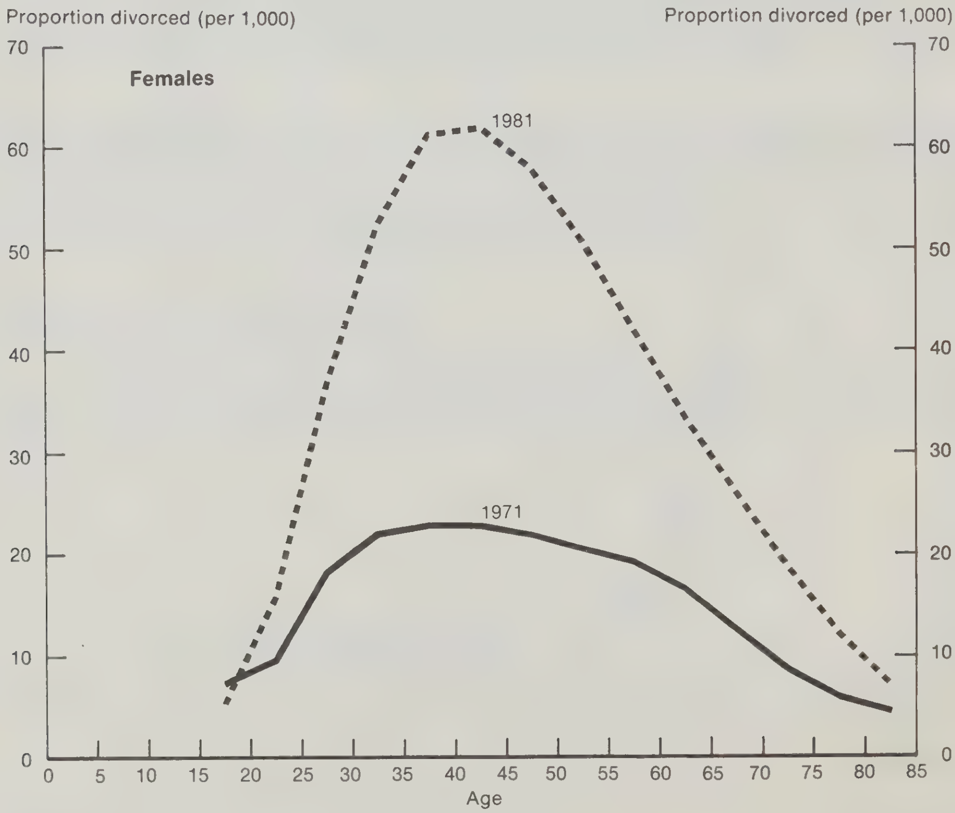


Source: Table 13.

Figure 7

Proportion Divorced Among Ever-married Persons, by Sex and Five-year Age Groups, Canada, 1971 and 1981





Source: Table 14.

TABLE 13. Proportion Single by Sex and Five-year Age Groups, Canada, 1971 and 1981

Age group	Males		Females	
	1971	1981	1971	1981
	per 1,000			
15-19 years	983.5	984.2	925.2	933.5
20-24 "	676.3	719.2	435.0	511.2
25-29 "	256.1	320.0	154.1	199.7
30-34 "	133.1	149.7	90.7	104.6
35-39 "	102.6	93.4	73.3	73.1
40-44 "	94.3	77.7	68.9	61.0
45-49 "	91.3	74.6	69.8	57.8
50-54 "	86.7	78.3	77.4	60.3
55-59 "	91.9	78.4	90.0	62.9
60-64 "	97.4	75.6	101.8	71.3
65-69 "	107.8	79.9	106.8	85.1
70-74 "	108.5	84.4	105.4	96.5
75-79 "	103.3	92.5	106.4	102.6
80-84 "	100.3	92.1	106.8	102.8

Source: Calculated from Statistics Canada, **Population. Marital Status by Age Groups, 1971,** Catalogue 92-730 and Statistics Canada, **Population. Age, Sex and Marital Status, 1981,** Catalogue 92-901.

TABLE 14. Proportion Divorced Among Ever-married Persons, by Sex and Five-year Age Groups, Canada, 1971 and 1981

Age Group	Males		Females	
	1971	1981	1971	1981
	per 1,000			
15-19 years	22.9	11.5	7.3	5.3
20-24 "	6.9	9.9	9.6	15.8
25-29 "	11.5	23.5	18.2	36.6
30-34 "	14.8	33.5	22.0	52.3
35-39 "	16.4	38.7	22.8	61.2
40-44 "	17.2	42.1	22.6	61.8
45-49 "	17.4	42.2	21.7	57.7
50-54 "	16.9	40.9	20.3	50.5
55-59 "	16.2	35.8	19.0	41.8
60-64 "	14.9	30.0	16.3	33.2
65-69 "	12.8	25.1	12.3	25.7
70-74 "	10.7	20.0	8.4	18.5
75-79 "	8.1	15.4	5.7	11.9
80-84 "	7.0	11.6	4.3	6.9

Source: See source, Table 13.

D-11: DESCRIPTORS OF HOUSEHOLDS AND FAMILIES

I DESCRIPTION

Definition

Statistical indices drawn from the distribution of households and families by size and composition, or from the distribution of the population by type of household and family.

Functions

In most countries, a "household" designates those persons who occupy the same dwelling. The household is thus a highly important socioeconomic unit for the study of consumer behaviour (including the use of medical services).

In censuses, a "family" designates a group of persons belonging to the same household and related, to a specified degree, by blood, marriage or adoption. The family is a very important biological and social unit that is relevant to various socio-medical issues.

II INTERPRETATION

Concepts Used in Canada

A household is made up of one person living alone or of all the individuals occupying a given dwelling. Private households are distinguished from collective households, the latter being made up of persons living in the same institution or the same commercial or communal establishment.

An "economic family" is a group of two or more persons living in the same dwelling and related by blood, marriage or adoption. Persons living in a common-law union also form an economic family.

The "census family" is also a group of two or more persons living in the same dwelling and related by blood, marriage or adoption; however, as opposed to the economic family, it comprises only the nuclear family made up of a couple alone, the couple and their unmarried children or one adult living with at least one unmarried child.

Two Significant Developments

Out of the many analyses of changing patterns in households and families, two have been found particularly significant.

The first deals with households made up of only one person (Table 15). These households are growing in number and involve an increasingly large proportion of the adult, and especially the elderly population. This may be an indication of a growing loneliness in society.

The second significant pattern concerns lone-parent families (Table 16). The proportion of these families in the total number of census families decreased until the 1960s, due to the decline in premature widowhood. It has increased steadily ever since, principally because of the growing number of separations and divorces during the child-raising period. This return to proportions already observed in the past involves a difference: today's lone-parent families are younger than those of former times.

TABLE 15. Persons Living Alone in Canada, 1951-1981

Year	Persons living alone	Persons living alone as a percentage of the population 15 and over	One-person households as a percentage of all households
1951	252,436[1]	2.6[2]	7.4
1956	308,613	2.8	7.9
1961	424,750	3.5	9.3
1966	589,571	4.4	11.4
1971	811,817	5.3	13.4
1976	1,205,340	7.0	16.8
1981	1,681,130	8.9	20.3

1 Excluding Yukon and Northwest Territories.
2 The Yukon and Northwest Territories were excluded from the population totals used to make these calculations, since the household figures used in the same calculations did not include this geographic area.
Source: Harrison, B., **Living alone in Canada: Demographic and economic perspectives, 1951-1976**, Catalogue 98-811, Statistics Canada, Ottawa, 1981, p. 16; and Statistics Canada, **1981 Census of Canada**, Catalogues 92-901, 92-904 and 92-905.

TABLE 16. Distribution of Families by Type, Canada, 1941-1981

Type of family		1941	1951	1961	1971	1981
Husband-Wife	No.	2,202,707	2,961,685	3,800,026	4,591,940	5,610,970
	%	87.8	90.1	91.6	90.6	88.7
Lone-parent	No.	306,957	325,699	347,418	478,740	714,010
	%	12.2	9.9	8.4	9.4	11.3
Total	No.	**2,509,664**	**3,287,384**	**4,147,444**	**5,070,680**	**6,324,980**
	%	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Wargon, S.T., **Children in Canadian Families**, Catalogue 98-810 Statistics Canada, Ottawa, 1979, p. 80; and Statistics Canada, **Census Families in Private Households: Persons, children at home, structure and type of living arrangements** (1981 Census of Canada), Catalogue 92-905, Ottawa, 1982, p. 4-1.

III TECHNICAL DISCUSSION

A detailed survey of the concepts and methods used for households and families in Canada may be found in:

Statistics Canada. Census Characteristics Division. **A User's Guide to 1976 Census Data on Households and Families,** by B. Harrison (Working Paper, Housing and Families Series, No. 1), 1979.

CHAPTER 4

DESCRIPTORS OF POPULATION CHANGE

This chapter will deal with descriptors drawn from annual statistics on the occurrence of demographic events in the population.

Among these descriptors, the best known are the crude rates, or annual numbers of demographic events of a given type per 1,000 population. These will be presented at the beginning of this chapter, except for the crude death rate, which will be discussed in detail in Chapter 6 (see I-01).

Three rather more complex synthetic indices will then be discussed: total fertility rate, total first marriage rate and total divorce rate. To avoid repetition, expectation of life at birth will only be presented in Chapter 6 (see I-03).

D-12: CRUDE RATES

I DESCRIPTION

Definition

Annual number of demographic events of a given type per 1,000 population.

Functions

The number of demographic events observed in a population depends above all on its size. This size factor, which is an obstacle to comparisons over time and space, is eliminated by the calculation of crude rates.

The most commonly used crude rates are those which give the annual frequency of entries to a population and exits from it: crude birth rate, crude death rate, crude immigration rate and, if available, the crude emigration rate. The difference between the first two crude rates is the "rate of natural increase", while the difference between the last two is called the "rate of net migration". The (total) growth rate is the sum of the two rates thus calculated.

II INTERPRETATION

From the graphic representation of natural increase in the Canadian population since 1921 (Figure 8), it can be seen that there is a great difference in the sensitivity of natality and mortality to socioeconomic conditions. Although mortality declined throughout the period, natality rose sharply after the slump of the 1930s. However, the concentration of couples around the ideal of two children, along with the availability of effective means of avoiding unduly large families, contributed to a new drop in natality during the 1960s, followed by a relative stability in the following decade.

Natural increase, or the difference between birth and death rates progressed in much the same manner as the crude birth rate. Traditionally ensured by medium-sized and large families, natural increase is today jeopardized by the widespread trend towards small families, which are barely large enough to ensure the replacement of cohorts.

Figure 9 shows the changes in the crude immigration rate since 1921. It will be seen that periods of economic or political crisis were unfavourable to immigration, while periods of expansion were favourable. It should be noted here that this is not permanent immigration, as many immigrants go back to their home countries or leave Canada to move to another country.[1]

III TECHNICAL DISCUSSION

A crude rate is normally obtained by calculating the ratio of the number of events (E) which occur during the year to the size of the population (P) at mid-year:

$$r = (E/P) \cdot 1{,}000$$

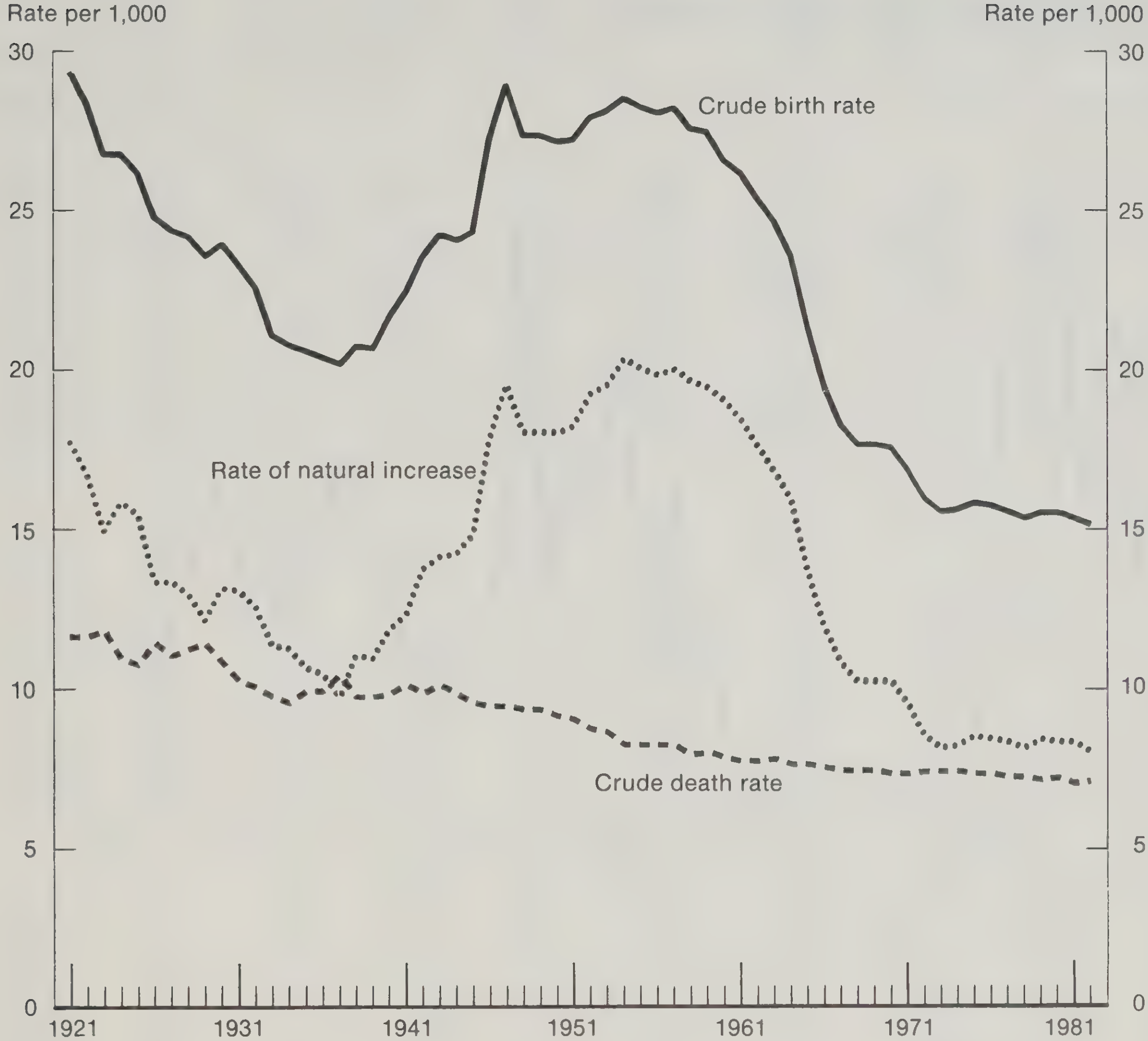
Crude rates thus only differ from one another by their numerators.

---

1 Péron, Y., "L'analyse par cohortes de l'immigration définitive", **Population,** Special Issue, September 1977, pp. 69-80.

Figure 8

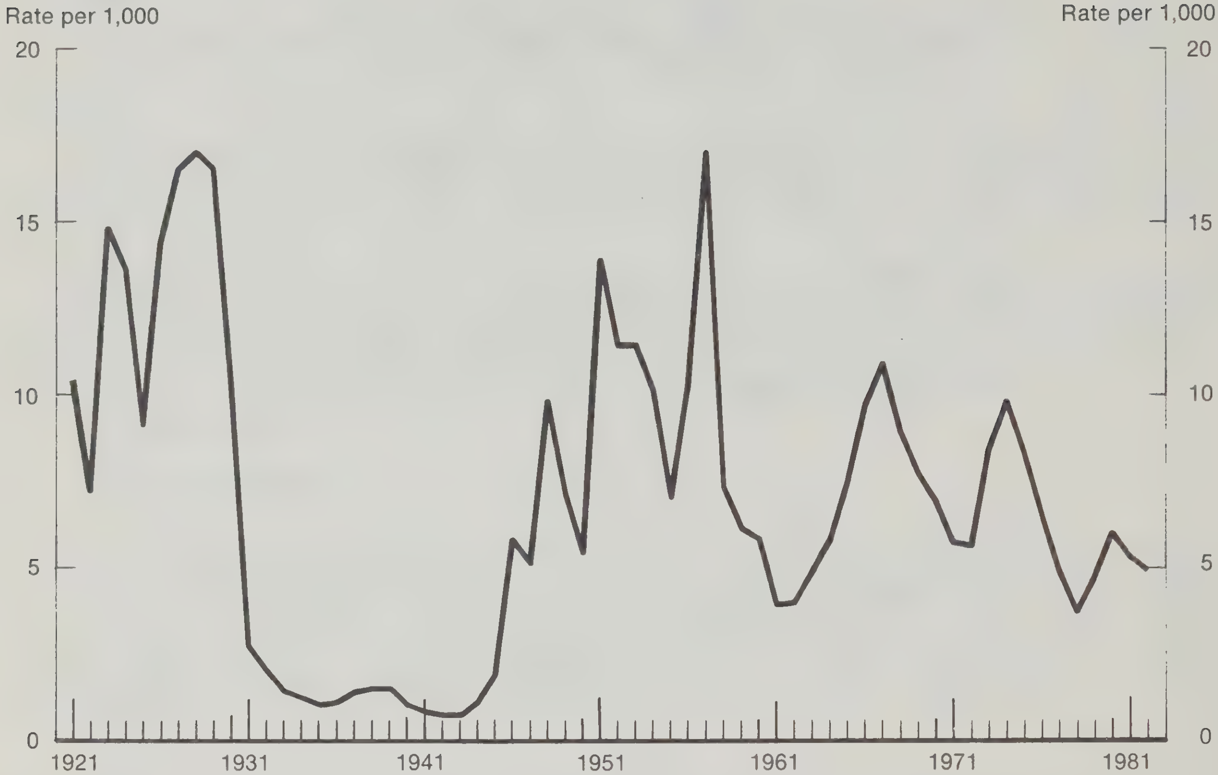
Natural Increase of the Canadian Population, 1921-1982



Source: Table 17.

Figure 9

Rate of Immigration in Canada, 1921-1982



Source: Table 17.

These numerators are provided by vital statistics (live births, marriages, deaths), legal statistics (divorces) and immigration statistics (landed immigrants). In the calculation of marriage and divorce rates, the number of marriages and divorces is sometimes replaced by the number of persons who experienced these events.

Depending on the estimates available, the figure taken as the denominator in calculating these rates will be the population on or around June 30 (June 1 in Canada), or else the arithmetic mean of estimates made for January 1 of two consecutive years.

TABLE 17. Components of Change in the Canadian Population, 1921-1982

Year	Crude birth rate[1]	Crude death rate[1]	Rate of natural increase	Rate of immi-gration	Year	Crude birth rate[1]	Crude death rate[1]	Rate of natural increase	Rate of immi-gration
		per 1,000					per 1,000		
1921	29.3	11.6	17.7	10.4	1951	27.2	9.0	18.2	13.9
1922	28.3	11.6	16.7	7.2	1952	27.9	8.7	19.2	11.4
1923	26.7	11.8	14.9	14.8	1953	28.1	8.6	19.5	11.4
1924	26.7	10.9	15.8	13.6	1954	28.5	8.2	20.3	10.1
1925	26.1	10.7	15.4	9.1	1955	28.2	8.2	20.0	7.0
1926	24.7	11.4	13.3	14.4	1956	28.0	8.2	19.8	10.3
1927	24.3	11.0	13.3	16.5	1957	28.2	8.2	20.0	17.0
1928	24.1	11.2	12.9	17.0	1958	27.5	7.9	19.6	7.3
1929	23.5	11.4	12.1	16.5	1959	27.4	8.0	19.4	6.1
1930	23.9	10.8	13.1	10.3	1960	26.8	7.8	19.0	5.8
1931	23.2	10.2	13.0	2.7	1961	26.1	7.7	18.4	3.9
1932	22.5	10.0	12.5	2.0	1962	25.3	7.7	17.6	4.0
1933	21.0	9.7	11.3	1.4	1963	24.6	7.8	16.8	4.9
1934	20.7	9.5	11.2	1.2	1964	23.5	7.6	15.9	5.8
1935	20.5	9.9	10.6	1.0	1965	21.3	7.6	13.7	7.5
1936	20.3	9.9	10.4	1.1	1966	19.4	7.5	11.9	9.7
1937	20.1	10.4	9.7	1.4	1967	18.2	7.4	10.8	10.9
1938	20.7	9.7	11.0	1.5	1968	17.6	7.4	10.2	8.9
1939	20.6	9.7	10.9	1.5	1969	17.6	7.4	10.2	7.7
1940	21.6	9.8	11.8	1.0	1970	17.5	7.3	10.2	6.9
1941	22.4	10.1	12.3	0.8	1971	16.8	7.3	9.5	5.7
1942	23.5	9.8	13.7	0.7	1972	15.9	7.4	8.5	5.6
1943	24.2	10.1	14.1	0.7	1973	15.5	7.4	8.1	8.4
1944	24.0	9.8	14.2	1.1	1974	15.6	7.4	8.2	9.8
1945	24.3	9.5	14.8	1.9	1975	15.8	7.3	8.5	8.3
1946	27.2	9.4	17.8	5.8	1976	15.7	7.3	8.4	6.5
1947	28.9	9.4	19.5	5.1	1977	15.5	7.2	8.3	4.9
1948	27.3	9.3	18.0	9.8	1978	15.3	7.2	8.1	3.7
1949	27.3	9.3	18.0	7.1	1979	15.5	7.1	8.4	4.7
1950	27.1	9.1	18.0	5.4	1980	15.5	7.2	8.3	6.0
					1981	15.3	7.0	8.2	5.3
					1982	15.1	7.1	8.1	5.3

1 Excludes Yukon and Northwest Territories from 1921 to 1923, and Newfoundland from 1921 to 1948; includes Quebec from 1921.

Sources: Crude birth and death rates: for 1921-1949, see Leacy, F.H. (Ed.), **Historical Statistics of Canada** (2nd Edition), Catalogue 11-516E, Statistics Canada, Ottawa, 1983, Series B4 and B18; after 1949, see Statistics Canada, **Vital Statistics,** Catalogue 84-204 (1975-1976, 1977 to 1982) and Catalogue 84-206 (1977 to 1982). Immigrants: Employment and Immigration Canada, **Immigration Statistics,** Supply and Services Canada, Ottawa; Population: Statistics Canada, **Revised Annual Estimates of Population by Sex and Age Group, Canada and the Provinces,** Catalogue 91-512 (1921-1971) and Catalogue 91-518 (1971-1976 and 1976-1981); and postcensal estimate of the population (1982).

D-13: TOTAL FERTILITY RATE

I DESCRIPTION

Synonym

Total fertility.

Definition

Statistical summary of age-specific period fertility, expressed as the average number of children born to women still alive at the end of their childbearing period.

Functions

Long chronological series of total fertility rates clearly show which periods have been favourable and which unfavourable to the formation of families and their rapid growth. On the whole, the medium-term trend of these rates is in the same direction as that of the completed fertility of successive female cohorts whose reproductive history is not yet terminated. Conversely, this synthetic index is almost always a poor estimate of the completed fertility of these cohorts.

II INTERPRETATION

In spite of the difference in method of calculation, this synthetic index is often taken to be the same as the average number of children ever born to women who have reached the height of their childbearing activity. To determine whether such an approximation is valid, it is necessary to look into the past and compare the annual values of the total fertility rate to the completed fertility of women who were at the mean age at childbirth during a given year of observation (Table 18 and Figure 10).

It may be seen from the graph that trends shown by the total fertility rate over the medium term are a good indication of changing levels of completed fertility. The slump in the rate during the 1930s was indeed a forecast of a decrease in the average number of children per woman in the cohorts which were then responsible for the greatest number of births. In the same way, the upward trend of the rate during the 1940s and 1950s foreshadowed an increase in completed fertility for succeeding cohorts. Changes in direction of these two descriptors did not, of course, coincide perfectly in time, but the lag was never more than two or three years.

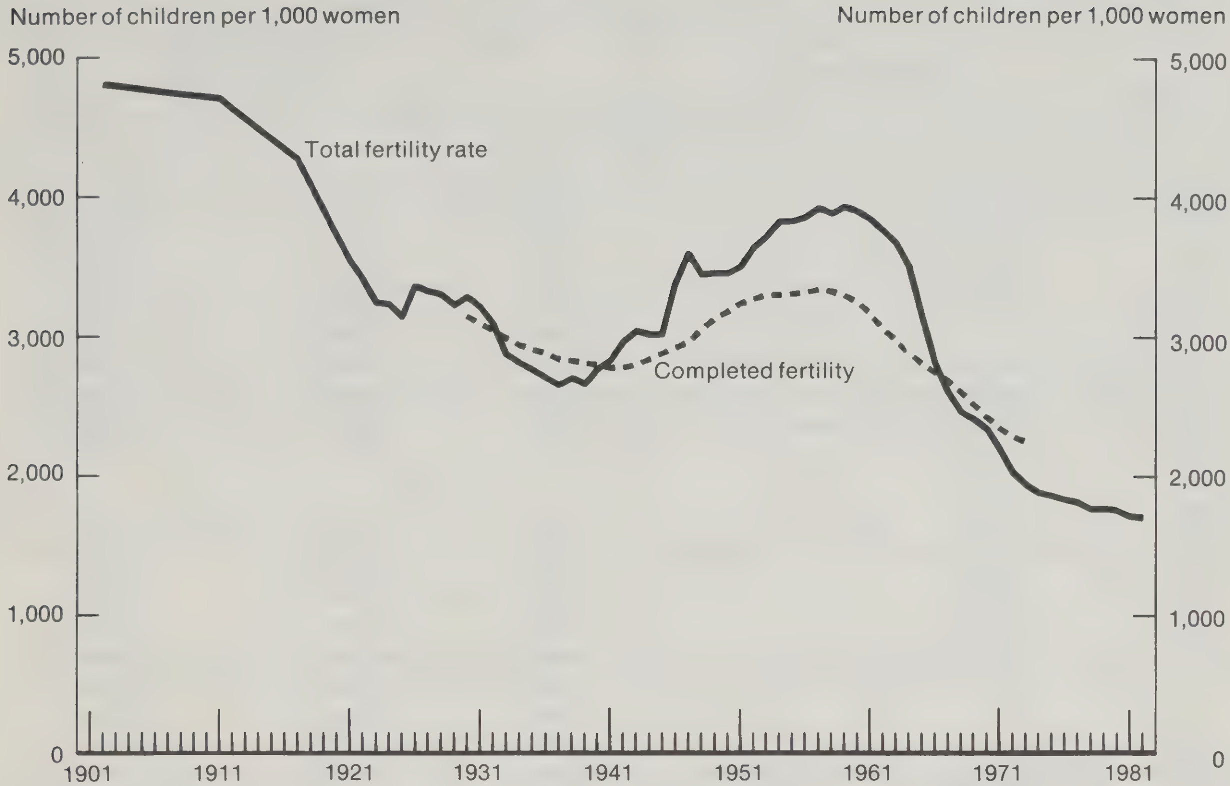
Paradoxically enough, it may also be seen on the same graph that the value of the total fertility rate was often quite different from that of the true completed fertility of women of childbearing age.

In cohorts responsible for births during the 1930s, for example, the average number of children per woman remained higher than what would have been anticipated based on the 1935-39 total fertility rates. Conversely, among the cohorts who contributed most to the post-war baby boom, none had completed fertility as high as that implied by the 1947-64 total fertility rates. This means that, on two occasions, and each time for several consecutive years, the total fertility rate was a poor predictor of the future completed fertility of cohorts.

The conclusion that must be drawn from this retrospective observation is that the total fertility rate gives reliable information on trends in completed fertility, but that the estimate it provides of the level of completed fertility is often unreliable. These two points should be kept in mind when interpreting more recent changes in the total fertility rate.

Figure 10

Trends in General Fertility, Canada, 1902-1982



Source: Table 18.

III TECHNICAL DISCUSSION

Calculating the total fertility rate

Using vital statistics and population estimates, one can calculate age-specific general fertility rates each year. For example, knowing that there were 18,144 live births during the year to women who were aged 20 at their last birthday and that the number of women of this age at mid-year was 215,690, the general fertility rate at age 20 can be calculated as follows:

$$f_{20} = (18{,}144/215{,}690) \times 1{,}000 = 84.1$$

The total fertility rate (S) is the sum of all the age-specific general fertility rates calculated in this manner for a given year, i.e.:

$$S = \sum_{x=15}^{49} f_x$$

Looking more closely at the formula for calculating the fertility rate, it can easily be seen that the sum of these rates yields the annual number of live births for a group of 1,000 women of each age included in the childbearing period. The total fertility rate thus enables one to follow changes in the number of births over time, controlling for changes in the size and age composition of the female population of childbearing ages.

TABLE 18. General Fertility in Canada, 1902-1982

Year	Total fertility rate	Completed fertility[1]
	per 1,000 women	
1902	4,800	
1907	4,740	
1911	4,700	
1912	4,620	
1917	4,260	
1921	3,536	
1922	3,402	
1923	3,234	
1924	3,221	
1925	3,132	
1926	3,357	
1927	3,319	
1928	3,294	
1929	3,217	
1930	3,282	
1931	3,200	3,080
1932	3,084	3,040
1933	2,864	2,980
1934	2,803	2,930
1935	2,755	2,900
1936	2,696	2,870
1937	2,646	2,830
1938	2,701	2,820
1939	2,654	
1940	2,766	2,790
1941	2,832	2,770
1942	2,964	2,780
1943	3,041	2,800
1944	3,010	2,840
1945	3,018	2,880
1946	3,374	2,920
1947	3,595	2,960
1948	3,441	3,050
1949	3,456	3,130
1950	3,455	3,180
1951	3,503	3,240
1952	3,641	3,270
1953	3,721	3,300
1954	3,828	3,300
1955	3,831	3,310
1956	3,858	3,320
1957	3,925	3,340
1958	3,880	3,320
1959	3,935	3,290
1960	3,895	3,240
1961	3,840	3,160
1962	3,756	3,050
1963	3,669	2,970
1964	3,502	2,880
1965	3,145	2,800
1966	2,812	2,740
1967	2,597	2,680
1968	2,453	2,600
1969	2,405	2,510
1970	2,331	2,420
1971	2,187	2,340
1972	2,024	2,280
1973	1,931	2,240
1974	1,875	
1975	1,852	
1976	1,825	
1977	1,806	
1978	1,757	
1979	1,764	
1980	1,746	
1981	1,704	
1982	1,694	

[1] Completed fertility of women who reached the mean age at childbirth during the year.

Source: Henripin, J., **Trends and Factors of Fertility in Canada,** Ottawa, D.B.S., 1972, pp. 30 and 33; Statistics Canada, **Vital Statistics, 1975 and 1976**, Vol. I, Births, Catalogue 84-204, p. 13; Statistics Canada, **Vital Statistics**, Vol. I, Births and Deaths (1978, 1980 and 1982), Catalogue 84-204 and Statistics Canada, **Technical Report on Population Projections for Canada and the Provinces, 1972-2001,** Catalogue 91-516, Ottawa, 1975, p. 72.

To grasp the reason why general fertility rates are summed, however, one must take a closer look at what each rate actually means. Since the number of women of age x varies from day to day by a fairly constant figure, the size of the group at mid-year is in effect very close to the arithmetic mean of the 365 or 366 daily totals. This size thus represents the number of years lived at age x between January 1 and December 31. Each general fertility rate consequently gives the number of live births per 1,000 years lived at the age for which it is calculated.

Let us then consider a group of 1,000 women who survive to the end of their childbearing period and who have, at each age, the fertility observed during the corresponding year. It is clear that these 1,000 women would give birth to a number of children equal to the sum of the fertility rates calculated during the year, i.e. the total fertility rate. By the use of this rate, fertility at a given moment can be summarized by a figure comparable to the completed fertility of a birth cohort (see D-04).

Total Fertility Rate and Completed Fertility of Birth Cohorts

The births in a given year are generated by some 30 female birth cohorts, each of which achieves part of its future completed fertility during the year. Insofar as the vast majority of women giving birth at age x belong to the cohort making up age group x at mid-year, it may legitimately be considered that the fertility rate at that age represents a fraction p_x of the future completed fertility D_x of that birth cohort:

$$f_x = D_x \cdot p_x$$

Consequently, the sum S of the fertility rates calculated during the year might be expressed as:

$$S = \sum_x D_x \cdot p_x$$

The total fertility rate may thus be interpreted as being a function of the completed fertility of birth cohorts and of the tempo at which this fertility is carried out.

It should be noted at this point that, if the tempo were the same for all birth cohorts, the sum of the quantities p_x would necessarily be equal to one, and the total fertility rate would be nothing more than the weighted average of completed fertilities D_x. The position of this mean would be determined by the more heavily weighted completed fertilities, i.e. those of cohorts at the peak of their childbearing activity. This synthetic index would then be an excellent predictor of future completed fertility for women of childbearing age.

Unfortunately, the tempo of general fertility changes from one birth cohort to another (see D-05), and the effect of these changes in tempo is to make the annual sum of proportions p_x not equal to one. The sum is greater than one when women tend to have their children earlier or make up for births postponed in the past, and less than one when contrary tendencies prevail. The total fertility rate is thus generally different from the future average completed fertility of birth cohorts. In fact, as was the case in 1935-39 and 1947-64, the total fertility rate may for some time be completely outside of the range of variation of the completed fertility of birth cohorts.

This sensitivity of the total fertility rate to changes in the tempo of fertility makes it a relatively unreliable predictor of the future completed fertility of women, since the error involved may be as great as 20% in either direction. This sensitivity is also responsible for the fact that the rate tends to amplify real variations in general fertility. In effect, variations in the total fertility rate are more pronounced than those in the completed fertility of birth cohorts, which is exactly opposite of what one would expect if it represented a moving average of these completed fertilities. In the past, however, distortions due to changes in tempo have never been great enough for the total fertility rate to show a lasting tendency to move in the opposite direction from completed cohort fertility.

Gross Reproduction Rate (period approach)

This is equivalent to the synthetic index just discussed, but expressed in terms of female births. It is thus obtained by multiplying the total fertility rate by the proportion of females at birth (0.488).

D-14: TOTAL FIRST MARRIAGE RATE

I DESCRIPTION

Definition

Annual summary of the nuptiality of single persons of each sex in the form of a number of first marriages before age 50 per 1,000 or 10,000 persons surviving at that age.

Synonym

First marriage frequencies.

Functions

This synthetic index facilitates comparisons over time and space, since it provides a figure for first marriages which is independent of the size and age composition of the population.

Since it is very sensitive to changes in age at marriage, this rate very effectively emphasizes the extent to which socioeconomic conditions are favourable or unfavourable to first marriages. For the same reason, its values often differ greatly from the frequency of marriage for a cohort.

II INTERPRETATION

As long as marriage was considered to be a necessary prerequisite to the formation of a couple, the propensity of single persons to marry remained strong and varied little from one cohort to another. Figure 11 clearly shows that this stability in the nuptiality of single persons was maintained in spite of the widely varying year-to-year changes in the total first marriage rate.

During the Depression of the 1930s, many people were unable to marry, and this is reflected by the low levels of the total first marriage rates. The majority of the marriages thus prevented were, however, recovered in later years, so that the cohorts most affected by the depression finally experienced a much higher nuptiality rate than that suggested by the period rates.

In the 1940s and 1950s, the synthetic index very often exceeded 1,000 first marriages per 1,000 persons still alive at age 50. It is known that the young people of that period tended to marry at increasingly earlier ages, while their elders were making up for time lost during the depression or the war, and this led to an accumulation of marriages spread over many ages. The paradoxical values of the period rate are a clear indication that such an accumulation could not have occurred for a single cohort.

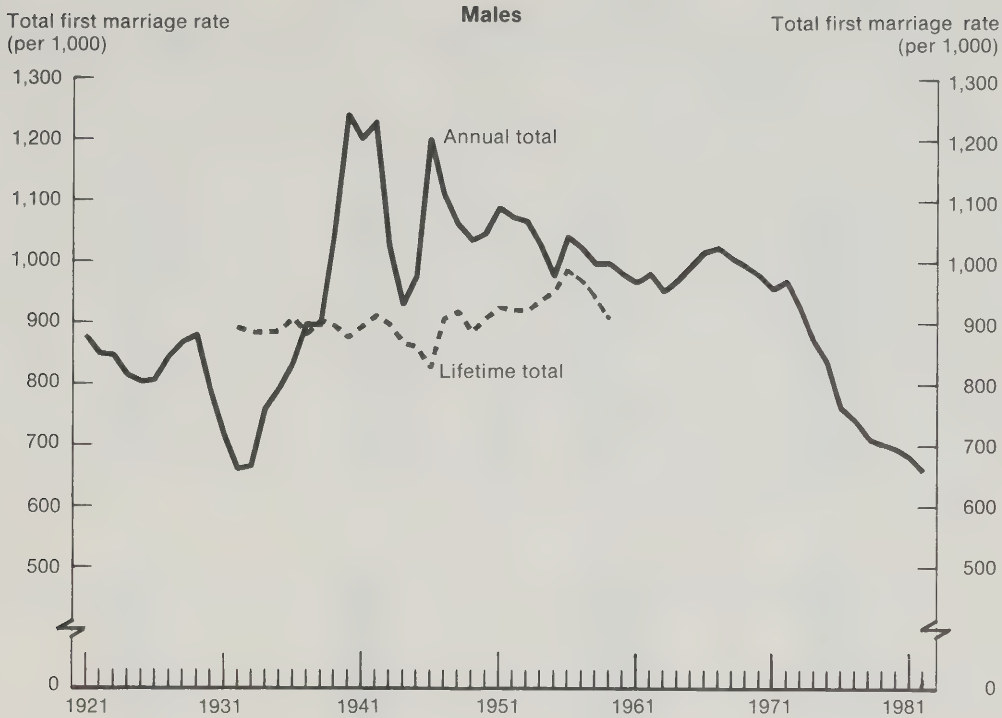
The wide variations in the total first marriage rate in the past thus basically reflected changes in the age at marriage from one birth cohort to another. The same would be true today if common-law unions were only a prelude to marriage. It is well known, however, that a growing number of couples have their children outside of marriage. In such a context, the recent drop in this index should be considered as the expression of the postponement of marriage to a later age in newer cohorts, as well as the refusal of marriage by a growing minority of couples.

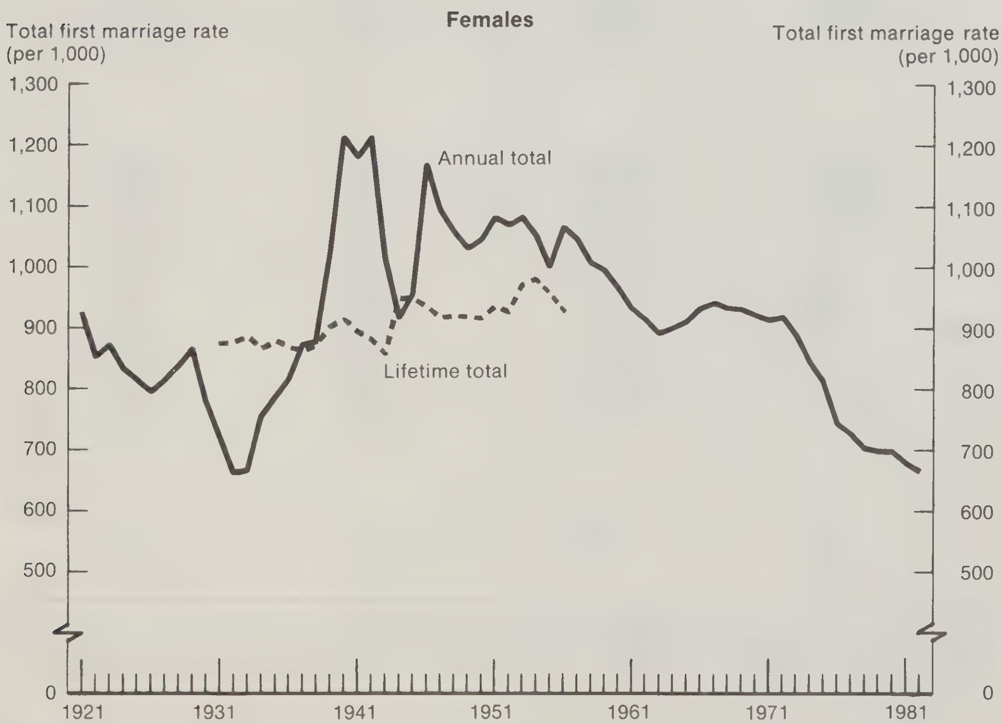
III TECHNICAL DISCUSSION

Calculation of the Total First Marriage Rate

This calculation is made separately for each calendar year and for each sex. For each age x, the ratio of the number of marriages among single persons during the year to the total number of persons in that age category at mid-year is calculated in order to obtain the marriage rates m_x. For

Figure 11
Trends in Nuptiality, by Sex, Canada, 1921-1982





Source: Tables 19 and 20.

TABLE 19. Total First Marriage Rate, Males, Canada, 1921-1982

Year	Annual total	Lifetime total[1]	Year	Annual total	Lifetime total[1]
	per 1,000			per 1,000	
1921	876		1951	1,088	924
1922	847		1952	1,072	919
1923	844		1953	1,065	919
1924	812		1954	1,027	935
1925	801		1955	976	951
1926	806		1956	1,041	987
1927	843		1957	1,021	965
1928	867		1958	996	942
1929	879		1959	997	912
1930	789		1960	979	
1931	714		1961	965	
1932	659	890	1962	980	
1933	665	882	1963	951	
1934	758	883	1964	969	
1935	791	885	1965	992	
1936	833	906	1966	1,016	
1937	897	880	1967	1,023	
1938	895	902	1968	1,005	
1939	1,045	893	1969	993	
1940	1,240	874	1970	977	
1941	1,200	892	1971	955	
1942	1,228	910	1972	968	
1943	1,025	896	1973	924	
1944	929	866	1974	870	
1945	976	858	1975	835	
1946	1,200	825	1976	760	
1947	1,109	906	1977	740	
1948	1,060	917	1978	710	
1949	1,034	883	1979	701	
1950	1,046	906	1980	693	
			1981	679	
			1982	657	

[1] For the cohort having reached the average age at marriage in the course of the year.

Source: Dumas, J., **Sixty Years of Nuptiality** ("Current Demographic Analysis" Series), Statistics Canada, Ottawa (forthcoming).

TABLE 20. Total First Marriage Rate, Females, Canada, 1921-1982

Year	Annual total	Lifetime total[1]	Year	Annual total	Lifetime total[1]
	per 1,000			per 1,000	
1921	924		1951	1,081	935
1922	851		1952	1,068	925
1923	871		1953	1,082	971
1924	832		1954	1,051	981
1925	813		1955	1,000	958
1926	794		1956	1,065	929
1927	813		1957	1,045	
1928	837		1958	1,006	
1929	864		1959	993	
1930	777		1960	965	
1931	718	873	1961	931	
1932	660	876	1962	913	
1933	666	885	1963	890	
1934	754	864	1964	900	
1935	786	878	1965	910	
1936	815	866	1966	932	
1937	873	860	1967	941	
1938	878	872	1968	931	
1939	1,025	902	1969	929	
1940	1,212	913	1970	920	
1941	1,180	892	1971	912	
1942	1,212	879	1972	928	
1943	1,013	856	1973	889	
1944	916	948	1974	844	
1945	956	947	1975	812	
1946	1,167	934	1976	742	
1947	1,093	915	1977	725	
1948	1,057	920	1978	701	
1949	1,030	916	1979	696	
1950	1,045	914	1980	696	
			1981	677	
			1982	663	

[1] For the cohort having reached the average age at marriage in the course of the year.

Source: See Source, Table 19.

example, if 21,546 single women aged 20 were married during a given year, and the number of single and ever-married women of that age was 221,190 at mid-year, the marriage rate at age 20 would be calculated as:

$$m_{20} = (21{,}546/221{,}190) = 0.0974 \text{ or } 97.4 \text{ per } 1{,}000$$

Summing these m_x values for each single age under 50 would give the total first marriage rate M for the calendar year in question.

Since the number of persons of age x at mid-year is equal to the number of years lived at age x during the period, m_x is the number of first marriages per year lived at that age (or per 1,000 years if m_x is expressed per 1,000). The total M is thus an estimate of the number of first marriages before age 50 for a group of persons still alive at that age.

Analysis of the Total First Marriage Rate (M)

One may take m_x to represent a fraction p_x of the total first marriage rate M_x of the cohort which forms the age category x at mid-year, this total being known once the members of that cohort have reached age 50. The annual total M may then be written:

$$M = \sum_x m_x = \sum_x M_x \cdot p_x$$

Thus M can be expressed in terms of the intensity and tempo of the nuptiality of single persons in various cohorts.

If age at marriage remains constant, the annual total of quantities p_x will always be equal to one, and the index M will be nothing more than the average of the intensity of marriage in the various cohorts M_x.

Had this been the case in the past, M would have varied little in the course of time, since it is now known that the intensity of nuptiality remained relatively stable from one cohort to another. This means that the wide variations in M in the past mainly reflect changes in age at marriage.

If all cohorts which are presently at marriage ages were to marry according to an identical age pattern one could say that the low values of M at the present time are a faithful reflection of the intensity of nuptiality of these cohorts. It is known, however, that the recent increase in consensual unions has upset the tempo of nuptiality by delaying many marriages, thus causing the annual total of quantities p_x to dip well below one. It is thus quite likely that persons now old enough to marry will do so in higher proportions than period indices would tend to indicate.

D-15: TOTAL DIVORCE RATE

I DESCRIPTION

Definition

Statistical summary of the frequency of divorces occurring during a given year in the form of a proportion of the couples who ever divorce.

Functions

Other things being equal, the number of divorces pronounced during a given year depends on the initial size and the marriage duration of the marriage cohorts who are subject to divorce that year. These factors of size and structure are eliminated here by calculating the annual number of divorces that would be associated with a uniform distribution of marriages over time (normally 1,000 or 10,000 marriages per year).

The result obtained is usually presented as the proportion of couples who ever divorce. Although this proportion is a poor estimate of the true propensity of couples to divorce, the trend it shows over the medium term is a good indication of changing patterns in divorce frequency within marriage cohorts.

II INTERPRETATION

In Table 21, changes in the total divorce rate in Canada can be followed since the new divorce act was passed in July 1968. The sustained increase over more than a decade bears witness to the unquestionable rise in divorces within marriage cohorts.

TABLE 21. Total Divorce Rate, Canada, 1969-1982

Years	Total divorce rate per 10,000 marriages[1]	Years	Total divorce rate per 10,000 marriages[1]
1969	1,370	1976	3,072
1970	1,863	1977	3,063
1971	1,885	1978	3,103
1972	2,007	1979	3,180
1973	2,233	1980	3,277
1974	2,673	1981	3,533
1975	2,932	1982	3,655

[1] Divorces before the 25th wedding anniversary.

Source: Table 48 in Dumas, J., **Report on the Demographic Situation in Canada 1983** ("Current Demographic Analysis" Series), Catalogue 91-209E, Statistics Canada, Ottawa, October 1984, p. 106.

Indications provided by this annual rate should not, however, be considered to apply strictly speaking to the marriage cohorts who benefited the most from the provisions of the new act. Although divorce most commonly occurs in the first 10 years of marriage, only 14% of couples married in 1967-68 had divorced by the end of 1980. At best, the total divorce rate could be considered as a prediction of the ultimate frequency of divorce in recently formed cohorts.

However, the quality of the prediction thus made is highly dependent on the greater or lesser stability of the distribution of divorces by duration of marriage in various cohorts, and trends have not favoured such stability. The new divorce act and a reduction in the social condemnation of divorce made possible a large number of unusually late divorces. Since this "catching up" phenomenon will become less and less important as time goes on, the period indices in Table 21 should be considered as overestimates of the ultimate frequency of future divorces for marriage cohorts formed in the past few years.

III TECHNICAL DISCUSSION

Calculating the Total Divorce Rate

If the divorces pronounced during year n can be classified by year of marriage, the number of divorces D_{n-x} among couples married during year n-x may be divided by the number of marriages M_{n-x} celebrated during that year in order to obtain the divorce rate at marriage duration x (x being expressed as a difference between year of divorce and year of marriage):

$$r_x = D_{n-x}/M_{n-x}$$

Once these ratios have been calculated for all marriage durations, they are added together, and the total thus obtained is called "total divorce rate for year n".

If the divorces pronounced during year n are classified by duration of marriage in complete years, it would be wise to take into account the fact that the number of divorces D_x which occur at duration x may be attributed to the two marriage cohorts formed during years n-x and n-x-1: the denominator of the ratio r_x would consequently be the arithmetic mean of the marriages celebrated during these two years.

Analysis of the Total Divorce Rate

Each marriage cohort yields during year n only a fraction of the total number of divorces it will ever experience. Divorces per marriage duration x thus represent only a proportion p_x of the total divorce rate R_{n-x} for the cohort formed by marriages during year n-x:

$$r_x = R_{n-x} \cdot p_x$$

The total divorce rate R for year n may thus be written:

$$R = \sum_x R_{n-x} \cdot p_x$$

The divorce rate observed in year n is thus a function of the ultimate proportions divorcing in the various marriage cohorts and of the distribution of divorces by duration of marriage.

Using exactly the same reasoning as described in the technical discussion of the total fertility rate, it may be shown that the total R would be a perfect predictor of the propensity of couples to divorce if the tempo of divorce were the same for all cohorts. Unfortunately, this is very unlikely, due to rapid changes in moral standards and legislation. As a consequence, less credit should be attached to the level of the total divorce rate than to its trend over the medium term.

Divorce Table (period approach)

When estimates are available of the number of couples surviving at mid-year by duration of marriage, a ratio may be calculated with the divorces observed at corresponding marriage durations to obtain "divorce rates for each year of marriage". These rates t_x may then be converted into "divorce probabilities q_x" using one or the other of the following formulas:

$$q_x = 2t_x/(2 + t_x) \quad \text{or} \quad q_x = 1 - \exp(-t_x)$$

The results are estimates of the probability of divorce within the next twelve months for couples still married at various anniversaries.[2]

Using these probabilities, it is possible to draw up a divorce table, following step by step the method used to compute a life table. This divorce table illustrates the progressive reduction in the number of married couples if divorce were the only means of ending a marriage, i.e. in the absence of widowhood. Table 22 gives an example for the American population.

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[2] Note that divorce tables are also calculated on the basis of age rather than duration of marriage. See Tables 7 and 8 in Adams, O.B. and Nagnur, D.N., **Marriage, divorce and mortality: A life table analysis for Canada, 1975-1977**, Catalogue 84-536, Statistics Canada, Ottawa, May 1981, pp. 40-41.

TABLE 22. Duration-of-marriage Table,[1] United States, 1976-77

Marriage anniversary x	Divorce probability[2] $_aq_x$	Couples intact at anniversary x	Divorces between x and x+a
0	0.0221	100,000	2,205
1	0.0422	97,795	4,126
2	0.0491	93,669	4,595
3	0.0503	89,074	4,479
4	0.0480	84,595	4,062
5	0.0441	80,533	3,551
6	0.0415	76,982	3,196
7	0.0386	73,786	2,851
8	0.0347	70,935	2,460
9	0.0319	68,475	2,183
10	0.0297	66,292	1,966
11	0.0278	64,326	1,788
12	0.0254	62,538	1,587
13	0.0225	60,951	1,374
14	0.0205	59,577	1,221
15	0.0806	58,356	4,701
20	0.0578	53,655	3,100
25	0.0368	50,555	1,860
30		48,695	

[1] For all marriages with divorce as the only form of marital disruption.
[2] This relates to couples who were intact at anniversary x, and gives the probability of divorce before anniversary x + a, with a being the interval between two successive anniversaries.

Source: Adapted from Table 2, in U.S. Department of Health and Human Services, National Center for Health Statistics. **National Estimates of Marriage Dissolution and Survivorship: United States** (Vital and Health Statistics, Series 3, No. 19), Hyattsville, Md., U.S. Department of Health and Human Services, 1980, p. 17.

PART II

THE USE OF DEMOGRAPHIC DESCRIPTORS AS INDICATORS OF THE HEALTH STATUS OF THE POPULATION

CHAPTER 5

DEVELOPING HEALTH STATUS INDICATORS

Once population structures and dynamics have been determined with the help of the demographic descriptors presented in the preceding chapters, the first two objectives of health planners are:

(a) to evaluate the health level of the population and how it varies over time,

(b) to draw up an inventory of the types of health problems encountered in the population, measure their impact on the population and its state of health and determine how these problems change over the years.

Once these goals have been attained, priorities regarding research or action may be identified.

At first glance, it might appear that the level of health of a population could be determined by averaging indices which summarize the state of health of the persons who make it up. As will be reiterated in the first part of this chapter, however, the health of an individual is a three-dimensional phenomenon (physical health, mental health, social health) which manifests itself in widely differing ways (well-being, ability to carry out certain basic activities, behaviour, resistance to illness, etc.). As a consequence, the state of health of individuals is generally defined by giving the greatest emphasis to one dimension, or to criteria which appropriately reflect the objectives that the definition's author has in mind. The choice of these criteria and their weighting with a view to arriving at an overall evaluation is largely arbitrary. Without going into detail regarding the controversy surrounding these questions, it might simply be observed that this method of estimating health levels in a population is still more the exception than the rule.

The planner will most often seek the answer to these questions of the state of health of the population in the body of statistics on mortality and morbidity. This is why it is wise to recapitulate for the reader certain concepts essential to a good understanding of these statistics (second section) and of commonly used descriptors (third section). It will then be easier to follow the planner in the selection of indices that are judged to be significant (fourth section).

HEALTH AND HEALTH STATUS

Dictionaries confirm the common usage whereby two different meanings are attributed to the word "health": on the one hand, it is a particular state of an organism allowing it to perform the normal activities of life, and, on the other hand, it is the general condition of the organism that can be qualified as involving "good" or "poor" health. This terminological ambiguity extends to scientific language as well.

Towards a Positive Definition of Health

For centuries humans lived under the constant threat of illness and premature death. Two centuries of economic, social and sanitary progress have greatly reduced the incidence of premature death, enabling growing numbers of people to live through all the stages of a complete life. Since each person's right to a long life is now fairly well ensured, it is normal that more questions are asked now than in the past about the quality of life.

The search for a positive definition of health is an attempt to provide answers to these questions about the quality of life. Health must be defined other than by the mere absence of illness or infirmity. One of the difficulties of such an undertaking rests precisely in the fact of leaving aside any reference to illness while attempting to characterize a particular condition of the organism which prevails only when all apparent morbidity disappears.

The most desirable manner of characterizing this state is to emphasize the notion of "well-being". This is what the authors of the constitution of the World Health Organization did when they wrote "health is a state of complete physical, mental and social well-being."[1] Insofar, however, as the feeling of well-being may turn out to be misleading, and since the state of well-being is difficult to verify, other authors prefer to resort to the expected manifestations of health. This is true of Bonnevie, who sees health as "a behavioural capacity - including biological as well as social components - to carry out basic functions".[2] To be even more positive, this behavioural capacity should lead to personal fulfillment and one might declare, as do Monnier and Deschamps, that "health is the equilibrium and harmony of all the possibilities of the human being: biological, psychological and social".[3]

It goes without saying that this equilibrium and this harmony presuppose particularly successful interaction between the people and the milieu in which they live. Through this interaction they are continually adapting to changing conditions which nevertheless remain capable of satisfying their needs. Adaptation and satisfaction of basic needs, satisfactory performance of basic functions, equilibrium and well-being, these then are the main signs by which health may be recognized.

The definitions just discussed are, of course, only a small sample of all the existing or possible definitions of health. Whatever definition one chooses to adopt or propose, however, health must be presented in all of its three dimensions (physical, mental and social) and be described using the concepts of well-being, ability to perform functions or adaptation. In this way, one will better identify that particular condition of a person which is alluded to in a somewhat confused manner when such expressions as "that person is healthy"or "he has regained his health" are used.

States of Health

As mentioned previously, the word "health" is also currently used to designate the general condition of the organism. The health of a person may then be qualified as deplorable, poor, fragile, delicate, good, excellent, etc., as the case may be. It is quite obvious that the frequency with which such adjectives are used proves that one spontaneously seeks to distinguish between various states of health and to classify them. But it must be admitted that these distinctions and classifications are normally established without first asking ourselves how health is defined, what criteria should be used and what constitutes the boundaries of the various states. This "states of health scale" to which reference is made in ordinary conversation is thus extremely vague; it may vary over time and from one person to another. Health professionals have accordingly been led to establish a scale that is more reliable and more appropriate to their needs.

The truly distinct states of health are certainly very numerous, but it may be supposed that they fall into a natural progression going from better (perfect health) to worse (the state of a person near death). Strictly speaking, this orderly classification of states of health is beyond our grasp. Nevertheless a representation or "photograph" of it can be obtained by proceeding as follows:

(a) using pre-selected criteria, divide all these states into classes, each class containing those states judged equivalent on the basis of the criteria used,

(b) call these classes "states of health" and arrange them in an order which seems to correspond to a worsening (or improvement) in health status.

This classification then constitutes a "health status scale". Let us look at a few examples, starting with the more simple and then moving on to the more complex.

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1 W.H.O., **Measurement of Levels of Health.** Report of a study group (Technical Report Series, No. 137), Geneva, W.H.O., 1957.

2 Bonnevie, P., "The Concept of Health. Sociomedical Approach", **Scandinavian Journal of Social Medicine**, 1,2, 1973, pp. 41-43.

3 Monnier, J. and Deschamps, J.P., **Santé publique. Santé de la communauté**, Villeurbanne, Simep, 1980, p. 11.

The simplest scale that could be imagined is one which allows the multitude of states of health which could ever be identified to be divided into two classes. It would be obtained using a single, dichotomous criterion. This is exemplified by the distinction frequently established between "positive health" and "negative health". In this case, morbidity is the only criterion used, and only two possibilities are distinguished: "apparent absence of illness" and "observed presence of one or more illnesses". Since it is quite obvious that they are considered desirable, states of health where illness is absent are called "positive", while the others are said to be "negative".

Even by using only one criterion, it is often possible to distinguish more than two possibilities in order to obtain a scale broken into a number of degrees. The following example is one proposed by J. and L. Lave and Leinhardt:[4]

- no symptoms
- mildly ill
- acutely ill
- critically ill
- apparent death

The criterion used here is subjective morbidity, that is, perceived by the individual or by an eyewitness. The states of health are classified by the severity of symptoms.

Taking into account several criteria in defining the scale brings up a number of methodological questions. This may be seen by examining the scale which often serves as a reference model, that of Grogono and Woodgate.[5] These authors took as their criteria 10 activities or important aspects of daily life: work, recreation, physical suffering, mental suffering, happiness, communication, dependency on others, sleep, eating, excretion and sexual activity. Each criterion offers three possibilities, which express the degree to which the individual's abilities are affected: normal, reduced or impaired, and incapacitated. The combination of these 10 trimodal criteria yields 3^{10} qualitatively different, and thus theoretically discernable, states of health. There is, of course, no question of listing each of these 59,049 states in an attempt to classify them from best to worst. Some means must therefore be found to divide these 59,049 states into a limited number of classes, each of which would include all the states deemed equivalent. Here is the method proposed by Grogono and Woodgate:

(a) for each criterion, each of the three possibilities shall be replaced by a score, which will in all cases be **1** for normal ability, **0.5** for reduced ability and **0** for incapacity,

(b) each state of health shall then be characterized by the arithmetic mean of the 10 scores assigned to the various criteria,

(c) those states of health receiving the same total score will be said to be equivalent.

Using this method, there would thus be only 21 distinct states of health in the scale, with total scores between **0** and **1**. It must, however, be noted that the scale thus obtained is based on a double weighting system (that of degrees of capacity and that of the 10 criteria), the validity of which may always be questioned. It might, for example, be asked whether the difficulty experienced in performing two given functions is really equivalent to the inability to perform a third, or whether the scores attributed to the three modalities really take into account the qualitative differences which exist between the various situations they cover.

Due to its complexity and multidimensional nature, the overall health of individuals, i.e. their health status, may be approached from many standpoints. It may be apprehended through the experience or perception of morbidity, through the greater or lesser degree of ability to perform the functions necessary to survival and life in society, or through the degree of perceived well-being. There thus exists a very wide range of situations, activities or perceptions which may potentially be

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4 Lave, J.and L. and Leinhardt, S., "Modeling the Delivery of Medical Services", in Perlman, M. (Ed.), **Economics of Health and Medical Care**, London, Macmillan, 1974, pp. 326-351.

5 Grogono, A.W. and Woodgate, D.J., "Index for Measuring Health", **The Lancet**, 11, 1971, pp. 1024-1026.

used in evaluating health status. This in turn leaves researchers considerable latitude in choosing exhaustive yet non-redundant criteria for the development of a health status scale that will suit their requirements.

In dealing with very large populations, this latitude is greatly reduced by the lack of statistics on many aspects of health status and by the impossibility of including in a single statistical document all the information collected on the various aspects of a given individual's state of health. Let us now look at what statistics are available and how they are analysed.

ANALYSIS OF RISKS OF MORTALITY AND MORBIDITY

The collection of a great mass of information on the negative health of populations has been made possible by the following developments: the recording of deaths in vital statistics, the inclusion in these records of details regarding the circumstances and medical causes of death, the administrative use of diagnoses made by doctors, and various epidemiological surveys. Some essential aspects of the analysis of this body of data will be briefly reviewed by looking successively at the analysis of mortality and morbidity risks, and then at the antecedents and consequences of diseases.

Analysis of Mortality Risk

The idea of analysing human mortality on the basis of sex, age and cause of death goes back to the origins of demography. As early as 1662, John Graunt was able to show how valuable information could be drawn from death records if these data were organized into statistical tables.[6] Using very rudimentary data, he even calculated the gradual decrease in the size of a cohort as a result of mortality. Some thirty years later (1693), the astronomer Halley drew up the first life table using statistics on deaths in the city of Breslau.[7]

Although in many developed countries the registration of deaths was made obligatory by civil and church authorities as early as the 17th century, the use of these registries for statistical purposes was introduced much later. This practice generally began in the 19th century, with the setting up of national vital statistics systems and the regular taking of population censuses. For several European countries, it is thus contemporary with the onset of the modern decline in mortality. This has meant that descriptors of mortality are now available for a very wide range of mortality levels, and this range has been increased by observations made in developing countries over the past two or three decades.

The existence of this large body of data has led demographers to search for standard patterns of variation in mortality according to age and sex. The experience gained in this research into model life tables shows that the various mortality structures by age may be summarized quite clearly by means of one or two parameters: expectation of life at birth, infant mortality rate, relationship between child and adult mortality, etc.[8] The predominant role attributed to these descriptors in estimating mortality as a whole is thus empirically justified.

The study of mortality is not confined to the examination of variations according to sex and age: it extends in particular to the analysis of causes of death. In conformity with the recommendations of the World Health Organization, cause of death is considered to be:

> "all those diseases, morbid conditions or injuries which either resulted in or contributed to death and the circumstances of the accident or violence which produced any such injuries."[9]

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6 Graunt, J., **Natural and Political Observations Made upon the Bills of Mortality,** London, 1662.

7 Halley, E., "An Estimate of the Degrees of Mortality of Mankind", **Philosophical Transactions,** 17, 1693, pp. 596-610.

8 For examples of standard tables see: Coale, A.J., Demeny,P. and Vaughan, B., **Regional Model Life Tables and Stable Populations** (2nd Edition), New York, Academic Press, 1983, viii + 496 p.; Lederman, S., **Nouvelles tables types de mortalité** ("Travaux et documents" de l'I.N.E.D., Cahier nº 53), Paris, P.U.F., 1969, xxi + 261 p. and United Nations. Department of International Economic and Social Affairs. **Model Life Tables for Developing Countries** (Population Studies No. 77), New York, U.N.O., 1982, vi + 351 p.

9 W.H.O., **Manual of the International Statistical Classification of Diseases, Injuries and Causes of Death,** Vol. I, Geneva, W.H.O., 1977, p. 699.

A death may thus have one or several causes. In the most complex cases, four types of causes of death may be distinguished if one considers the chronological order of the morbid events which preceded the death, and the causal relationships which may exist between these events:

(a) the **direct** cause, which is responsible for the fatal outcome,

(b) the **underlying** cause, which initiated the sequence of morbid states leading to the appearance of the direct cause and of death,

(c) the **intervening** causes which, since they made up the sequence of morbid conditions leading to death, served as a link between the two preceding causes,

(d) **contributing** or **concomitant** causes which, although unrelated to the direct cause, nevertheless had an unfavourable influence on the course of the morbid process which led to death.

Thus, in the case of a person who died of uremia (direct cause), the underlying cause of death could be hypertrophy of the prostate, the intervening cause the retention of urine, and the other ailments of the deceased would then only act as contributing or concomitant causes. In such cases, the informants, who are almost always doctors, must attempt to establish a hierarchy among the various causes of death; in fact, the very structure of the death certificate invites them to do this.

The fact remains, however, that out of this varied body of causes, the statistician normally retains only one: the underlying cause. This choice may be explained by the priority given to prevention over therapy. From this point of view, it is more important to know the origin of fatal processes than their terminal development. For the same reason, the statistician is more interested in the circumstances of the accident or violence which led to the death (**external** causes of death) than in the nature of the injuries experienced by the victim. Since they are intended to assist in decision-making with respect to prevention, current statistics thus consider as the cause of death:

> "(a) the disease or injury which initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury."[10]

Strictly speaking, and with rare exceptions, it is the statistics of death by underlying cause that are being considered.

With these statistics, general mortality may be broken down into a great many particular types of mortality, each of which may be due to a given underlying cause or group of causes of death. Each particular type of mortality is then analysed on the basis of age at death and sex. Life tables are even computed to estimate the risk of mortality from each cause or the number of years of life which might be gained by eliminating a given cause. In order that the results may be comparable over space and, if possible, over time, underlying causes of death are selected according to the rules laid down by the World Health Organization, and then subdivided using an international classification known as the "International Classification of Diseases, Injuries and Causes of Death" (abbreviated as I.C.D.). Begun in 1855 by William Farr, this classification was completed in 1893 by Jacques Bertillon. It has been widely used since that time, although it has been amended about every 10 years to take into account scientific advances and changing information needs. The last revision - the 9th to date - was in 1975.

Studying underlying causes of death is already an important first step towards a thorough study of the occurrence of disease in the population. From this one can go on to the rather complex study of morbidity.

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[10] W.H.O., **op. cit.**, p. 700.

Analysis of Morbidity Risk

The concept of morbidity, which appeared shortly before the mid-19th century, has been refined as a result of attempts to control the spread of infectious diseases. The risk of morbidity was thenceforth considered from two points of view: incidence and prevalence.

The **incidence** of a disease is the frequency with which **new cases** appear in the population during a given interval of time. Annual incidence, for example, might be calculated by computing the ratio of the number of new cases discovered during a year of observation to the size of the population at the middle of that year (**incidence rate**). Incidence rates are normally calculated according to sex and age in order to bring to light those periods of life when the disease most frequently occurs (**critical ages**).

The **prevalence** of a disease is the proportion of persons suffering from the disease in the population at a given time, or occasionally during a given period. Prevalence is linked to incidence by the average duration of the disease. Thus, if the average duration of a disease is two years, the number of individuals affected at a given time would be double the annual number of new cases. For an equal rate of incidence, chronic diseases thus have a higher prevalence rate than acute ailments. For the same reason, therapeutic practices which enable sufferers to survive without being cured contribute to widening the gap between prevalence and incidence.

Now that these definitions have been clarified, the next step is to examine the problem of observing diseases. To approach this difficult problem it is necessary to review the usual timing of a disease as described by Wood.[11]

The first phase of the disease is **latent**: pathological transformations, i.e. unfavourable changes in the structure of the body or its functions, appear and develop without the individual's knowledge, over a period which may extend from a few days to several years. This latent phase comes to an end when, alerted by signs or symptoms, the individual realizes that a pathological state exists or is informed of this by another person: the disease is then **exteriorized**. By reason of this condition or its perception, the person experiences an alteration in ability to function and in behaviour: the disease is then **objectified**. Finally, abnormalities of appearance or of body functioning, or disturbances in behavioral ability place the individual at a disadvantage with respect to others and transform the disease into a social disadvantage: this is the **socialization** phase of the disease.

It may be seen that this outline defines three levels of experience of the disease - exteriorization, objectification and socialization - through which it is possible, by surveying the population directly, to determine the prevalence of **perceived morbidity**. This does not constitute total true morbidity, since latent morbidity is necessarily excluded. This type of morbidity, long neglected by the health sciences, is attracting more and more attention, if only because of its determining role in the demand for medical or paramedical care.[12]

When persons feel ill, they may seek the services of a doctor. The doctor then attempts to identify the disease from which the patient is suffering in order to prescribe treatment. The fraction of morbidity thus isolated is called **diagnosed morbidity**. It is a measure of the activity of the health care system and, for this reason, knowledge of it is invaluable to those managing the system. Due to this interest, a number of statistics of administrative origin are available, the best known being hospital morbidity statistics. The picture these statistics give of the morbidity of a population must be interpreted with caution due to the intrusion of many exogenous factors: variability of perception of treatment requirements depending on disease and social milieu, availability and accessibility of medical services, etc. In the case of serious illnesses for which a doctor must be consulted sooner or later, the systematic collection of diagnoses permits the setting up of disease registers, such as cancer registers or acute myocardial infarction registers, which are very useful in estimating the incidence of these diseases in the population.

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[11] W.H.O., **International Classification of Impairments, Disabilities and Handicaps**, Geneva, W.H.O., 1980, 210 p.

[12] Lévy, É., Bungener, M., Duménil, G. and Fagnani, F., **Économie du système de santé**, Paris, Dunod, 1975, 354 p.

A more satisfactory means of determining the prevalence of diseases would be to systematically examine the entire population. This would give **"objective" morbidity**, that is, morbidity which can be detected in the present state of medical concepts, norms and methods. The cost of such an undertaking would, however, be prohibitive, and it could thus only be envisaged for limited groups representative of all or part of the population.

Different estimates of morbidity correspond to these three modes of observation and, **in principle**, these estimates follow this pattern:

diagnosed morbidity	<	perceived morbidity	<	objective morbidity

Statistics on objective morbidity provide the best indication of the various morbidity risks to the population, other statistics normally only give a partial measure (diagnosed morbidity) or an unspecified measure (perceived morbidity). This means that, in most cases, the risks are only truly known for a few diseases which have been the focus of special epidemiological studies or for which registers have been established.

Antecedents of Disease

In the past the epidemiological study of communicable diseases revealed a great variability in the resistance of individuals to disease. This variability was not a matter of chance. On the contrary, certain identifiable factors caused a clear predisposition to illness. In the case of tuberculosis, for instance, these were age, malnutrition, overwork, alcoholism, overcrowding and unhealthy conditions in dwellings, etc. Bringing these antecedent factors to light was a major development in organizing prevention of these diseases.

Over the past 30 years, similar observations have been made for a number of now highly prevalent chronic ailments. The appearance and development of these diseases are linked statistically to certain characteristics of the person, including lifestyle and environment. From a public health standpoint, following Grundy, these characteristics may be classified into three groups: precursors, risk factors and risk markers.[13]

Precursors are biological abnormalities detectable before the appearance of the first symptoms or clinical problems characteristic of the disease. In the case of myocardial infarction, these could be high cholesterol levels or an abnormal electrocardiogram. Due to the length of the latent phase of certain diseases, it is sometimes difficult to determine whether these abnormalities are antecedent to the onset of the disease or its first manifestations.

Risk factors are the other characteristics which, appearing before the onset of the disease, may be controlled by clinical, epidemiological or other intervention. Habits such as heavy smoking or drinking, or environmental factors such as air and water pollution, are good examples of this. The effect of these factors depends on the intensity and duration of exposure, and may influence both the appearance and the development of the disease.

Risk markers are characteristics of individuals or their environment which are uncontrollable or can be controlled only with difficulty. Typical examples are sex, age, ethnic group and climate. Although they may be modified, attributes such as marital or socioeconomic status should be considered as risk markers insofar as treatment of the disease is normally reconcilable with their continued existence. Risk markers are ordinarily considered as signs of a greater vulnerability to the action of risk factors.

Consideration of these three categories of factors - precursors, risk factors and risk markers - permit the identification of high-risk groups which should be the first to benefit from disease-control programs. These programs are aimed at reducing the prevalence of precursors and the exposure to risk factors, and reducing their detrimental effect on health. An important and often-asked question is then the following: is there a rational basis for such action? This could be rephrased as: do such actions really tackle the causes of disease?

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[13] Grundy, P.F., "A Rational Approach to the 'At Risk' Concept", **The Lancet**, 2, December 29, 1973, p. 1489.

It must be understood that bringing to light one risk factor or another is based, at the outset, on empirical observations which reveal that, all other identifiable things being equal, sick persons have been more exposed to the factor than others, or that, under identical conditions, individuals exposed to this factor fell ill more frequently. However, statistical relationships such as these are not sufficient to establish a causal relationship between exposure to a risk factor and the frequency of a disease. The fact that smokers develop lung cancer more often than non-smokers is not **in itself** sufficient proof that heavy smoking is to blame in the etiology of that cancer, since smokers may differ from non-smokers in other unidentified characteristics which are nevertheless determining factors in the onset or development of the disease. The etiological role of this risk factor was in fact only confirmed once the 10 modern postulates of causal research in medicine, as stated by A.M. Lilienfeld,[14] had been gradually satisfied:

1. prevalence of the disease should be significantly higher in those exposed to the hypothesized cause than in control groups not so exposed,

2. exposure to the hypothesized cause should be more frequent among those with the disease than in those without the disease - when all other risk factors are held constant,

3. incidence of the disease should be significantly higher in those exposed to the cause than in those not so exposed, as shown by prospective studies,

4. temporally, the disease should follow exposure to the hypothesized causative agent with a distribution of incubation periods on a bell-shaped curve,

5. a spectrum of host responses should follow exposure to the hypothesized agent along a logical biologic gradient from mild to severe,

6. a measurable host response following exposure to the hypothesized cause should have a high probability of appearing in those lacking this before exposure, or should increase in magnitude if present before exposure; this response pattern should occur infrequently in persons not so exposed,

7. experimental reproduction of the disease should occur more frequently in animals or man appropriately exposed to the hypothesized cause than in those not so exposed; this exposure may be deliberate in volunteers, experimentally induced in the laboratory, or may represent a regulation of natural exposure,

8. elimination or modification of the hypothesized cause should decrease the incidence of the disease (i.e. removal of tar from cigarettes, attenuation of a virus),

9. prevention or modification of the host's response on exposure to the hypothesized cause should decrease or eliminate the disease (i.e. immunization, drugs to lower cholesterol),

10. all of the relationships and findings should make biologic and epidemiologic sense.

Proving such a causal relation thus requires a great variety of studies. These are long and difficult due to the long latency period of chronic diseases, the multiplicity of their probable causes, and the absence of a unifying concept which would bring together all the observations concerning a given disease. Where action is required, the decision whether to proceed or not must often be based on certain assumptions of causality, which will be used to evaluate the positive and negative effects to be expected from each alternative.

Precursors and risk factors are not always specific to one and the same disease, since some of them are common to a number of diseases. This is the case, for instance, with cigarette smoking, which is a risk factor for chronic bronchitis, coronary heart disease, lung cancer, etc. Any attempts to control these two categories of factors in fact represents an attack on a relatively wide range of diseases and health problems.

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[14] Taken from Strasser, T., "À propos de l'article de J.-L. Richard: Lipides alimentaires, cholestérolémie et cardiopathies ischémiques", **Revue d'Épidémiologie et de santé publique**, 28, 4, 1980, p. 486.

Precursors and risk factors constitute a threat to the future health of persons who experience them or are exposed to them. These persons may therefore be considered potential sufferers. This is **potential morbidity**, knowledge of which is necessary for decision-makers and which, in turn, becomes an area of study. For example, studies might be made of the spread of the smoking epidemic in order to determine its psycho-social and economic determinants or research into hypercholesteremia might be directed to discovering its probable origin in eating habits developed during childhood or adult life, etc. Through this process of tracing back the determining factors of disease, new avenues of intervention may be discovered.

The Consequences of Disease

From phenomena antecedent to the disease, let us now turn to those which follow it, i.e. the consequences of disease.

Illness is responsible for a certain number of behaviour patterns: absenteeism from school or work, medical consultations, consumption of pharmaceutical products, etc. This body of disease-induced conduct constitutes what is sometimes called **behavioural morbidity**. Analysis of this type of morbidity is interesting from two points of view. First, it shows that these individual responses to disease are inextricably linked to a whole social and cultural context which must be understood if the data are to be properly interpreted. Second, the study of behavioural morbidity reveals the complex network of social and economic repercussions of disease, including its inconvenience and cost for individuals, their families, schools or professional milieus and the community as a whole.

The effects of disease on an individual are usually described as deviations from a norm. Health professionals call these deviations impairments, disabilities or handicaps. The meaning of these terms is not always well defined and often varies from one person to another. To remedy this state of affairs, the World Health Organization recently proposed a number of definitions which will be presented in the following paragraphs, even though they are not yet widely used.[15]

Impairments are deviations from biomedical norms. More specifically, "an impairment is any loss or abnormality of psychological, physiological or anatomical structure or function". They thus include abnormalities in appearance and body structure as well as defects in a functional system, including the reduction of mental faculties.

Disabilities are deficiencies in the performance of certain everyday tasks considered normal to a human being: washing, dressing, feeding, walking, etc. A disability then represents "any restriction of ability to perform an activity in the manner or within the range considered normal for a human being". It is the consequence of one or more impairments.

A **handicap** is "a disadvantage for a given individual that limits or prevents the fulfilment of a role that is normal (given the age, sex and social and cultural factors)". Any person who, simply because of disabilities or impairments, is at a disadvantage in life in society compared to peers may be considered as handicapped. This is the case for persons who cannot easily communicate with those around them, earn their living, look after themselves, etc.

In this series of consequences, impairment is always the phenomenon that necessarily precedes manifestation of the other two. A disability, however, is not always followed by a handicap, and a handicap may exist without disability. As opposed to impairments, disabilities and handicaps must be classified according to degree and not only according to their nature.

These effects of disease may disappear at the same time as their cause or they may persist after the disease has disappeared. They may be permanent or temporary, and may worsen or regress with time. Although these effects are normally taken into consideration in evaluating the health

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15 W.H.O., **International Classification of Impairments, Disabilities and Handicaps**, Geneva, W.H.O., 1980, pp. 27-29.

status of patients, their prevalence in the population is generally poorly understood due to the lack of appropriate statistics. It is, however, known that this prevalence increases with the increasing predominance of chronic illnesses and aging of the population.

Another possible consequence of disease is death which, in a manner of speaking, may be thought of as a generalized impairment or disability. The **lethality** of a given disease is the proportion of cases which are followed by a fatal outcome, attributable to that disease. The number of deaths attributable to the disease in question is thus the product of its incidence by its lethality. As a result, cause of death statistics give an incorrect picture of the incidence of various diseases. When there is little variation in lethality over time and space, however, differences observed in the mortality attributed to a given disease reveal existing differences in the incidence of that disease. Consequently, cause of death statistics are frequently and legitimately used when, as is often the case, morbidity statistics are lacking.

Advances in the analysis of the risk of morbidity and mortality have led to the development of many new descriptors of morbidity and mortality. Let us now see how these are organized, in order to get a better appreciation of their interest and applications.

RELATIONSHIPS BETWEEN DESCRIPTORS OF MORBIDITY AND MORTALITY

After drawing up a schematic representation of the sequence of facts related to disease, descriptors will be divided into two categories, depending upon whether they express a particular phenomenon or a relationship between different phenomena.

Sequence of Stages Related to Disease

The sequence of stages discussed in the foregoing section are represented schematically in Figure 12. Moving from left to right, one first has the antecedents of disease (precursors and risk factors), then the morbid conditions (diseases and accidents), and then the various consequences of these conditions (behavioural changes, impairments, disabilities, handicaps, death). The arrows indicate only the time sequence in which these elements occur, since the time lapse between their occurrence is obviously quite variable, and in fact later stages may not even appear in some cases.

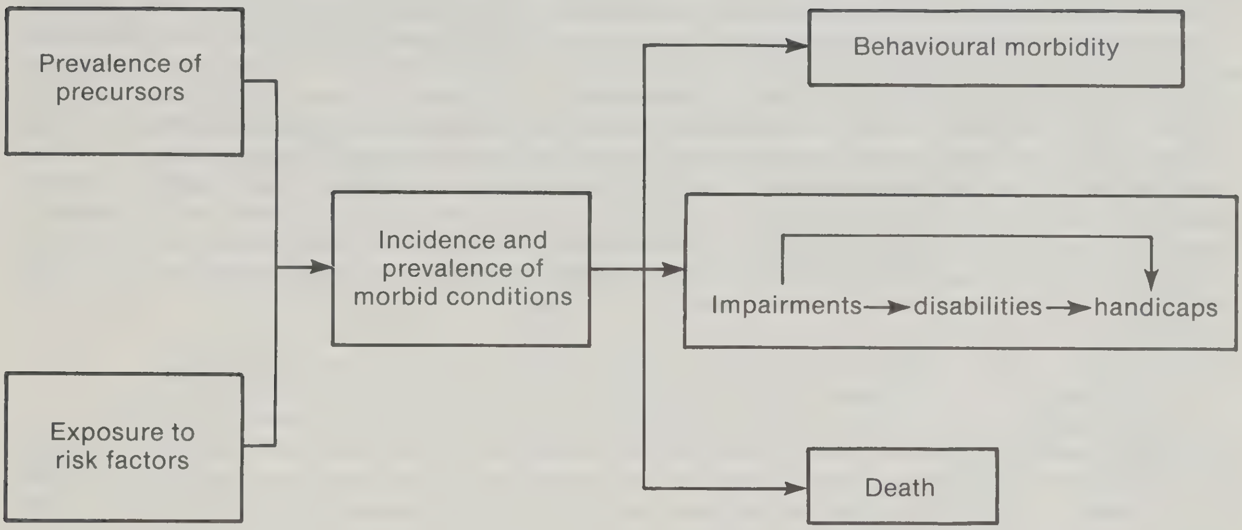
It should be clear that this diagram is a simplified view of what really happens. Certain morbid conditions, such as diabetes or high blood pressure, are precursors or risk factors of other diseases. As well, certain consequences of disease, such as impairment or death, often have precursors or risk factors that are different from those of the disease. The diagram is nevertheless useful in emphasizing the various types of action that could be taken against disease and its sequelae.

While treatment must necessarily be placed after the diagnosis of an illness or its recurrence, preventive measures may be spread throughout the sequence described by the diagram. **Primary prevention** is aimed at diminishing the incidence of disease through an attempt to limit the prevalence of precursors and exposure to risk, as well as reducing the vulnerability of the population to these antecedents of disease. **Secondary prevention** seeks to limit the duration of the disease, and thus its prevalence, by early diagnosis and treatment of the first signs of disease. **Tertiary prevention** attempts to prevent recurrences and, through rehabilitation and social and professional reintegration, to reduce the prevalence of disabilities and handicaps. For proper planning of these preventive and curative measures, the entire sequence of disease-related events must be taken into consideration.

A number of descriptors are available for this sequence, and these may be divided into two categories, which will be discussed below.

Figure 12

Sequence of Stages Related to Disease



Descriptors of Specific Phenomena

Descriptors dealing with a single phenomenon will be placed in this category. Using terminology borrowed from Lévy, **et al.**,[16] these descriptors may be divided into three groups according to the sequence of appearance of the phenomena involved:

(a) **descriptors of exposure**, which indicate the prevalence of precursors or the exposure to risk factors,

(b) **descriptors of morbid conditions**, which are the various measurements of incidence and prevalence of diseases,

(c) **descriptors of outcome**, which measure the impact of morbid conditions on the population by the extent of their various consequences (general mortality, prevalence of disability or handicap, reduced activity, use of medical services, etc.).

Bringing together all these descriptors makes it easier to take an inventory of the health problems faced by the population. However, since these descriptors are developed independently of one another, the links between the various health problems are not always evident.

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[16] Lévy, É., **Économie du système de santé, op. cit.**

Descriptors of Relationships Between Phenomena

In this second category will be placed descriptors derived from an analysis of the phenomenon when it is studied in the light of another phenomenon that necessarily precedes it. Two groups may be distinguished: measures of linkages between two phenomena and measures of the combined effect of two phenomena.

The descriptors in the first group are obtained by noting the number and frequency of manifestations of the phenomenon under study among persons who have already experienced the preceding phenomenon. For example, if the phenomenon studied is mortality, these descriptors would be obtained by calculating the frequency of deaths in groups of sick persons, persons exposed to a risk factor, or carriers of a precursor. Life tables have thus been drawn up for cancer patients, smokers, people with high blood pressure, etc. On a more refined level of analysis, one would attempt to calculate risks of death from various diseases, risk factors or precursors. Of the total risk of death, only that part directly related to the preceding event that is being considered would be retained. Using the same examples as above, one would no longer be measuring the risks of death of cancer sufferers, smokers or people with high blood pressure, but rather calculating what part of these risks may be attributed to cancer, smoking or high blood pressure. These more elaborate descriptors, apart from the fact that they may only be calculated through the comparison of groups who have or have not experienced the chosen antecedent, differ from those mentioned earlier in this paragraph in that their goal is more ambitious: bringing to light probable cause and effect relationships.

The descriptors in the second group are measures of the impact of a given phenomenon on a second phenomenon which occurs after it. Using the example above, if the second phenomenon is mortality, the descriptors sought might be the number of deaths due to a given disease or a given risk factor and the frequency of such deaths in the population. As mentioned, mortality attributable to a disease is, subject to certain hypotheses which will be discussed later, the product of the incidence of the disease multiplied by its lethality. In the same way, mortality attributable to a risk factor is the product of the degree of exposure of the population to this risk factor multiplied by the risk of death which is attributable to it. In judging the impact of one phenomenon on a second, two elements must therefore be taken into consideration: the frequency of manifestations of the first phenomenon and the causal relation between manifestations of the first phenomenon and those of the second.

All these descriptors of relationships are obviously very useful, since they enable one to partially overcome the tendency to break the health situation of a population down into phenomena and problems which are analysed separately. Hopefully, advances in observation and knowledge will add to this group of descriptors, which at present is quite small.

DEVELOPING INDICATORS OF THE HEALTH STATUS OF THE POPULATION

In the beginning of this chapter, it was said that, once the health planner has identified the population of concern, the first two objectives are:

(a) to evaluate the health level of the population and how it varies over time,

(b) to draw up a list of the main health problems faced by the population by area of intervention, measure the impact of these problems on the population and determine how they change over time.

To reach these objectives, it is necessary to extract from a great mass of statistics those which are deemed to be the most significant. Let us see how this can be done.

Indicators of Level of Health

Long before the term "indicator" was first created, certain descriptors were already being used to follow changes in the level of health of populations. These were mainly descriptors of mortality: crude death rate, infant mortality rate, expectation of life at birth. Mortality, both by its level and its trends, was then considered as representative of the whole range of phenomena related to health, of which it constitutes a partial synthesis.

This reasoning is still valid insofar as mortality, coming at the end of a sequence of disease-related events, is a phenomenon which integrates the combined effects of several health related phenomena that precede it in the sequence: exposure to risk factors, prevalence of precursors, occurrence and lethality of diseases. Its representative nature is, however, contested for several reasons:

(a) the increasing share of chronic diseases in morbidity as a whole has considerably modified the relationship between the incidence and prevalence of diseases, causing an ever-growing distortion between trends in mortality and morbidity,

(b) this growing predominance of chronic disease also changes the situation with regard to disease sequelae, giving a greater share to disabilities and handicaps,

(c) by reducing the short-term lethality of certain congenital or chronic diseases, modern medicine has succeeded in bringing about a regression in mortality while allowing the prevalence of disease and disability to increase.

As a result of this, workers have proposed various formulas which would combine mortality with other disease consequences, particularly disability. The most interesting proposals in this area are those aimed at defining expectation of life in good health, i.e., the average number of years during which an individual would be free of the more severe consequences of disease.

Whether descriptors of mortality are used alone or in combination with other descriptors, however, the synthesis they express of health phenomena is never complete. Then one has indicators rather than descriptors of health levels, and it is hoped that the trends they exhibit will be a faithful reflection of improvement or deterioration in the real health level of the population. To verify this, it would be necessary to compare them with a true index of health level.

Development of such an index is still hampered by a number of conceptual, methodological and practical problems.[17] The activities, behaviour patterns and perceptions to be taken into account in determining the state of an individual's health are so numerous that, until they have been proven to be interchangeable, there will always be some doubt as to how valid their selection is and how each should be weighted. As well, criteria and norms to be used will necessarily vary from one group of people to another, for example, the same criteria and norms could not be used indiscriminately to evaluate the health of a child, an adult or an elderly person. In spite of considerable research, many problems have yet to be solved before there is agreement on an operational definition of a single index of the health level of an entire population.

An indicator of health level is essentially synthetic, and obviously does not reveal the nature of the health problems to be solved. Other more specific indicators will thus be necessary to suggest appropriate action.

Indicators of Health Problems

One of the health planner's first tasks must certainly be to draw up a list of the principal health problems facing the population. Many very useful descriptors are available for this purpose. Descriptors of exposure will show to what extent the population is exposed to recognized risk factors

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[17] Goldberg, M., Dab, W., Chaperon, J., **et al.** "Indicateurs de santé et 'sanométrie': les aspects conceptuels des recherches récentes sur la mesure de l'état de santé d'une population", **Revue d'épidémiologie et de santé publique**, Vol. 27, 1979, pp. 51-68 and 133-152.

and how this exposure changes over time. Descriptors of morbid conditions will indicate the frequency of perceived or diagnosed morbid states, the most common pathological conditions and thus the vulnerability of the population and its exposure to specific risks. Descriptors of results will reveal the extent and diversity of disease sequelae in the population.

The planner will then seek to classify the various health problems that have been identified by their impact on the population and its health status. The significance of a disease or a risk factor will be judged by the number and frequency of premature deaths attributable to them, by the number of years of life thus lost, by the risks of disability and handicap caused by them, etc. Here again, there are a number of descriptors and, occasionally, a number of synthetic indices that summarize the impact of disease on the overall health of individuals. Those health problems which most affect the population and its health status will, of course, be considered most in need of a solution.

The nature and impact of health problems obviously depend on the period of life during which they appear. Risk factors, pathological conditions and various changes in health take on different patterns at different ages. The earlier in life a health problem appears, the greater is likely to be its impact on the population and its health status. The listing and classifying of health problems should therefore be carried out by making use of descriptors specific to various stages of life and various phases in the life cycle of the family.

In the evaluation of the health level of the population, and the identification of its main health problems, the planner makes frequent, although not exclusive, use of demographic descriptors. These are consequently promoted to the rank of indicators of the health status of the population.

These demographic indicators will be presented in the next three chapters in the following sequence:

- indicators of the level of health (Chapter 6),
- indicators of health problems (Chapter 7),
- indicators specific to certain stages of the life cycle (Chapter 8).

As in the case of descriptors, the indicators are presented individually. The interpretation given of each is mainly destined to emphasize their respective functions and to underscore their advantages and limitations, using the criteria normally employed to evaluate indicators.

CHAPTER 6

INDICATORS OF THE LEVEL OF HEALTH

In this chapter, the following five indicators will be discussed:

- crude death rate,
- standardized death rate,
- life expectancy at birth,
- life expectancy in good health,
- quality-adjusted life expectancy.

Each of these indicators is presented separately with the exception of the last, which is derived from life expectancy in good health.

In each case, an attempt is made to specify the nature of the indication each gives of the health level of the population: actual mean health, intrinsic mean health and mean positive health. It is hoped that this will contribute to a better understanding of the specificity of each indicator.

I-01: CRUDE DEATH RATE

I DESCRIPTION

Definition

Annual number of deaths per 1,000 population.

Descriptive Function

This rate, which is the simple ratio of the number of deaths recorded during the year to the size of the population at mid-year, is a measurement of the annual frequency of deaths as well as a statistical summary of age-specific death rates. The same result would be obtained by calculating the weighted mean of these specific rates, using the age-specific distribution of the population as weighting coefficients.

Indication Sought

This would be the actual mean health level of the population. It is assumed that this level varies in the same manner as mortality, but of course in the opposite direction.

II INTERPRETATION

Health Status and Mortality

Some scales of health status are numerical, each status level being summarized by a score which may, for instance, vary from **0** (very poor health) to **1** (excellent health). The use of these scales in surveys is the same as giving a health score to each person questioned or examined. Thus one may calculate:

- the average m_x of the scores obtained by the members of age group x,
- the average M of the scores obtained by all persons participating in the survey.

If p_x designates the proportion of population in age group x, the overall average M may be written:

$$M = \sum_x m_x \, . \, p_x$$

This overall average M may serve as an indicator of the average health of the population surveyed. In this case, one would speak of **actual** mean health, to emphasize the fact that it depends not only on average health at various ages, but also on the age-specific distribution of the population.

Unfortunately, there is no numerical scale of health status which is universally accepted and applicable to all stages of the life cycle. Moving from the study of specific sub-populations to that of the population as a whole, this average M thus remains unknown. To follow changing patterns in the actual average health of the population, one must look for an alternative indicator. This indicator might be given by a series of indices t_x well correlated to the series m_x, provided of course that one also calculates the average of this series using coefficients p_x drawn from the age-specific distribution of the population.

Among the indices t_x which might be chosen are age-specific death rates, whose corresponding average is nothing other than the crude death rate. A number of good arguments may be offered for the existence of a strong negative correlation between mortality and health status:

- death is the ultimate deterioration in health, and some authors consequently consider the prognosticated mortality risk as an important dimension of individual health status,[1]
- death and other alterations in health have a common origin in exposure to the same risk factors and in the prevalence of the same precursors,
- analyses of both mortality and the occurrence of many health problems place the emphasis on similar risk markers (sex, age, marital status, occupation, income, etc.).

To this body of assumptions may be added the empirical observations presented below.

Confirmation by Observation

During spring and summer 1965, a survey was carried out among 7,000 adults residing in Alameda County (California) to determine their health status and health practices. The data provided by informants made it possible to rank them according to seven states of physical health:[2]

- **severely disabled**, which is manifested by ceasing work and serious difficulties in performing everyday activities for six months or more,
- **lesser disability**, demonstrated by a restriction of household activities and a change in work habits for at least six months,
- **presence of two or more chronic conditions** (diabetes, hypertension, etc.) for the past year or more, but not causing disability at the time,
- **presence of one chronic condition**,
- **presence of symptoms** (cramps, paralysis, chest pains, etc.) for the past year or more,
- **without complaints, but medium or low energy**, this being a state characterized by a recurrent impression of tiredness,
- **without complaints, high energy**.

Health practices were evaluated using eight criteria involving cigarette and alcohol consumption, physical activity, hours of sleep and eating habits. If the person's lifestyle was favourable to health for at least five of the eight criteria, their health practices were considered good, otherwise they were labeled poor.

Later on, in the early 1970s, examination of death certificates issued in California from 1965 to 1970 inclusive made it possible to calculate the risk of death over five and a half years in the group of adults surveyed in 1965. This calculation was made for each of the sub-groups distinguished by health status and health practices in mid-1965. Table 23 shows the results obtained, adjusted for the unequal distribution by age of the various sub-groups.

Before commenting on these results, it should be recalled that the sample under observation is fairly small (7,000 persons), so that groups of persons of the same sex and having the same health status and health practices always involved less than 900 members, and in some cases less than 100. Consequently, the deaths in each group were limited in number and the death risks calculated could be affected by sizeable random errors. Therefore the apparent "anomalies", which may well not be significant, will be ignored in order to look only at the major trends.

There are three significant points:

- mortality varies with health status in the expected direction; this is very clear for men, although less so for women,
- whatever the health status, mortality also varies with health practices in the expected direction,
- for both men and women, those persons having poor health practices or suffering from very poor health status show higher than average mortality.

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1 Mizrahi, A. and A., **Les indicateurs synthétiques de santé au niveau individuel**, Paris, C.R.E.D.O.C., 1981, 14 p.
2 Belloc, N.B., Breslow, L. and Hochstim, J.R., "Measurement of Physical Health in a General Population Survey", **American Journal of Epidemiology**, 93, 1971, pp. 328-336.

TABLE 23. Age-adjusted Mortality Rates (5½ years) by Physical Health Status and Health Practices, by Sex, Alameda County, California

Physical health status	Mortality rates			Health practices			
	Males	Females	Total	Males		Females	
				Poor	Good	Poor	Good
Severely disabled	0.143	0.097	0.120	0.159	0.114	0.100	0.116
Lesser disability	0.097	0.042	0.070	0.124	0.080	0.065	0.032
Two or more chronic conditions	0.065	0.038	0.051	0.095	0.048	0.059	0.026
One chronic condition	0.058	0.030	0.044	0.062	0.054	0.043	0.031
Symptoms	0.045	0.036	0.040	0.038	0.033	[1]	0.047
Without complaints, medium or low energy	0.063	0.033	0.048	0.073	0.036	0.071	0.030
Without complaints, high energy	0.030	0.043	0.036				
Total	**0.066**	**0.044**	**0.055**				

[1] Too few deaths to calculate age-adjusted rate.

Source: Taken from Tables I and VI in Belloc, N.B., "Relationship of Health Practices and Mortality", **Preventive Medicine, 2, 1973, pp. 67-81.**

Certain particularities of the survey should be taken into consideration when interpreting these conclusions. The health status of individuals was determined from statements made by those surveyed, and these statements were probably more objective in the case of disability and chronic ailments than for symptoms or fatigue. Discrimination between the poorer states of health is thus probably more valid than that between the better states of health. In addition, the health status observed is that of 1965, and it may reasonably be assumed that subsequent deterioration was more common than improvement due to aging of individuals during the following five years. These two arguments could contribute to weakening the relationship established between mortality and health status. The introduction of health practices into the analysis brings a welcome addition, insofar as it results in the distribution of persons according to the prognoses of future changes in their health status. One can easily assume that the chances of a given state of health improving or stabilizing are better with good health practices than with poor ones. It appears that groups with poor health practices deteriorated more than the others in the health status scale over the period 1965-1970. It is then quite understandable that the mortality of these groups during the period was higher than average, especially since their point of departure (in 1965) was already poor. It may be concluded that the link between mortality and physical health would appear even stronger if the sample size had been large enough to allow for a shorter period of observation.

Meaning of Mortality Descriptors

The survey just described clearly confirms the existence of a link between mortality and physical health. This link would take the form of a negative correlation if better health states are attributed higher scores on the scale. Mortality descriptors thus appear to be acceptable indicators of the physical health of a population.

The indication which may be derived from these descriptors depends on how the correlation established is temporally situated. If one is very restrictive and requires that mortality descriptors provide information on the health of the population at the time of death, it is clear that the indication provided will show a prevalence of very poor states of health, since in the short-term these states are responsible for the greatest number of deaths. If, however, a lagged correlation is envisaged, the indication given is of a higher significance. As in the California study, mortality recorded over a certain period of time is then associated with a health situation prior to the observation of death, so that all states of health make some contribution to this mortality. As is

clearly shown in Table 23, the mean frequency of deaths in the population depends not only on the earlier prevalence of very poor states of health, but also on the intensity of forces pushing towards a betterment or worsening of the health of persons in the other health status categories. Bearing in mind a certain degree of time-lag, mortality thus reflects both the structure of a health situation (distribution of the population by various states of health) and its dynamics (respective importance of factors favourable and unfavourable to future health).

Interest and Limits of the Crude Rate

Of all the descriptors of mortality, the crude rate is the easiest to obtain, since it is simply the ratio between the number of deaths recorded in a year and the size of the population in the middle of that year. In the technical discussion, it will be shown that this simple ratio is nothing more than the average of age-specific death rates. If T is the crude rate, t_x the death rate at age x and p_x the proportion of persons at age x in the total population, the following equation may be established:

$$T = \sum_x t_x \cdot p_x$$

This formula is interesting because it emphasizes the composite nature of the crude death rate.

From the above formula, it is clear that the value of the crude rate depends on age-specific variations in mortality (series t_x) and on the age-specific distribution of the population (series p_x). The crude rate is consequently a reflection of both health conditions and the population state in terms of its age distribution. It is equivalent to the mean of the individual health indices of persons making up that population.

The age structure of a population, which is a function of changing patterns in past fertility and migratory movements, normally only changes slowly. The result is that **short-term** changes in the crude death rate are mainly caused by changes in health conditions. This is particularly true for variations throughout the year of the **monthly death rates** (see technical discussion), since these variations are generally speaking a reflection of seasonal changes in the health status of the population. This remains true for a limited series of annual rates, provided that variations observed from year to year are sufficiently clear: a sharp rise in the rate would indicate the severity of an epidemic or the impact of a natural catastrophe, while a series of variations in the same direction would indicate an improving or worsening trend in health conditions, depending on the direction of the trend. These well-known facts show that the crude rate reacts in a specific way to significant and rapid changes in the health status of the population.

On the other hand, gradual changes in the age pyramid of the population can have a considerable effect on **medium** or **long-term** patterns in the crude death rate. This may be seen by comparing the actual pattern to that which would have been observed if there had been no change in the composition by age (see Figure 13 in I-02: Standardized Death Rate). In particular, in an aging population, the crude rate decreases less rapidly than the decrease in mortality risks at various ages, due to the increase in the proportion of older persons, who are the most exposed to death. It should, however, be emphasized that population aging has just as unfavourable an effect on improvement of the actual mean health of the population, since, because of their age and the associated accumulation of health risks, the elderly do not enjoy as good health as do adults and children. Of all the descriptors of mortality, the crude rate is the only one whose trends are affected by this factor of resistance to improvement in the health of the community as a whole. It is thus legitimate to use it when one specifically wants to take into account aging of the population.

The main objection to the use of the crude death rate is its lack of reliability for comparisons between populations. When the populations compared enjoy fairly similar health conditions at the various ages, then the series of crude rates obtained will provide an acceptable indication of their rankings in terms of **actual mean health**. If the contrary is true, however, crude rates with the same value could be obtained in situations that differ widely in terms of demographic and health aspects. This quite frequently happens in comparisons between industrialized countries and developing countries due to the compensation between the advantages the former gain from their lower mortality and that the latter derive from the greater youth of their population. Use of the crude death rate is thus not recommended for comparisons between countries in different parts of the world.

III TECHNICAL DISCUSSION

Statistical Sources and Calculation Methods

National statistical agencies regularly publish crude death rates and the data required to calculate them. Number of deaths and rates appear in annual vital statistics reports, while population estimates are often published in separate documents.

The crude rate is always calculated on a yearly basis and the result is expressed per 1,000 population. Depending on the length of the observation period, it is calculated in one of the following ways:

- deaths observed during a single complete year are expressed as a ratio of the mid-year population,
- deaths observed during a period of more than one year are expressed as a ratio to the total of the population sizes at the middle of each of the years included in the period or, failing this, of the length of the period multiplied by the population size at mid-period.
- the mean number of daily deaths observed during a month is expressed, after being multiplied by 365, as a ratio of the population size at mid-month to obtain a monthly rate expressed on a yearly basis, i.e. having the same order of magnitude as an annual rate.

The Crude Rate as the Average of the Age-specific Rates

Proper understanding of the crude death rate requires that one follows a tangent that is not necessary to its calculation. Let us do this by means of an example.

Table 24 presents some Canadian statistics for the year 1981: deaths recorded during the year, and population on June 3. If on each line the ratio between the number of deaths and the corresponding population size is calculated, four deaths rates will be obtained, one for each of the three age groups and the crude rate. The reader may easily check that the crude rate may be obtained by multiplying each age-specific rate by the proportion of persons in the corresponding age group, then adding together the three products. Thus the crude rate is the weighted average of the age-specific rates.

This property of the crude rate T may be summarized as:

$$T = \sum_{x} t_x \cdot p_x$$

t_x being the death rate at age x (specific rate) and p_x the proportion of persons in age group x.

TABLE 24. Crude Death Rate and Age-specific Death Rates, Canada, 1981

Age	Deaths in 1981	Size of population on June 3, 1981	Rate (per 1,000)
0-14 years	5,430	5,481,110	1.0
15-64 "	50,934	16,501,100	3.1
65 years and over	114,616	2,360,975	48.5
All ages	**170,980**	**24,343,185**	**7.0**

Source: Statistics Canada, **Vital Statistics, 1981**, Vol. I, Catalogue 84-204, Table 18 and Statistics Canada, **1981 Census of Canada**, Catalogue 92-901.

I-02: STANDARDIZED DEATH RATE

I DESCRIPTION

Synonyms

Adjusted mortality rate or standardized mortality rate.

Definition

Annual number of deaths per 1,000 population which would be observed in the population if it had the same age composition as a reference (or "standard") population.

Descriptive Function

As risks of dying vary widely by age, the annual frequency of deaths in a population depends on its age composition. Standardized rates permit this exogenous factor to be eliminated in comparative mortality studies.

Indication Sought

Relative levels of intrinsic mean health of different populations at a given time, or of a given population at different times.

II INTERPRETATION

Crude Rate and Standardized Rate

Figure 13 shows the actual development of the annual frequency of deaths in the Canadian population since 1921 (crude rate curve), as well as that which would have been observed if the age composition of that population had always remained the same as at the time of the June 1956 census (standardized rate curve). The difference between the two curves is only due to differences between the actual age distribution of the population and that of the standard population. This explains why it is nil in 1956, minimal for the five or six years prior to and following 1956 and widens as one moves further away from 1956 in either direction. It will also be seen that there was a sign change in the difference after 1956. This is because the Canadian population has aged since that date, comparative to its previously younger age structure. Because of population aging, the annual frequency of deaths has thus decreased less than the decline in the risk of death at various ages.

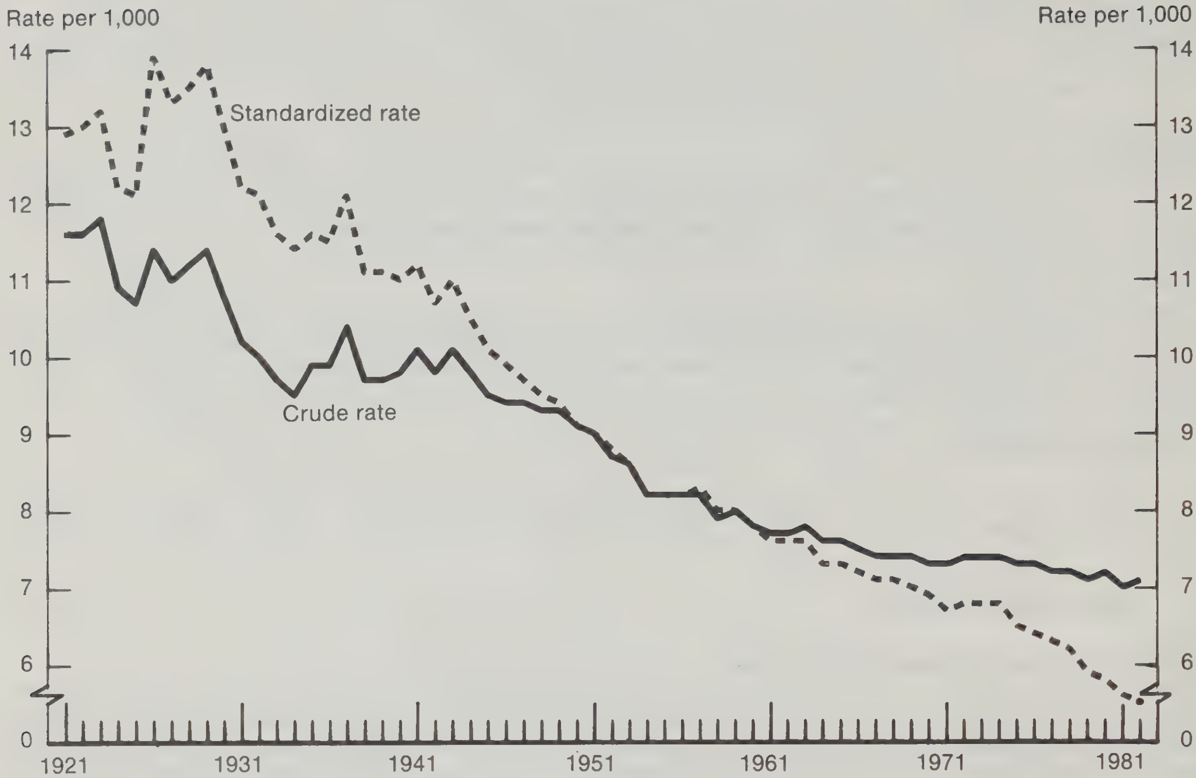
The impact of changes in the population age pyramid on the annual rate of death is commonly measured by the ratio of the crude rate to the standardized rate. In our example, this ratio was 1.29 in 1982 (Table 25). This means that population aging between 1956 and 1982 was responsible for a surplus of 29% in the number of deaths per 1,000 population in 1982. Consequently, the annual rate of death declined by only 13.4% between 1956 and 1982, while it would have decreased by 32.9% if the age composition had remained unchanged.

This numerical example and the graph that has been reproduced should suffice to show the great sensitivity of the crude rate to differences in the age structure of populations. This is why, in studies on the geography of mortality, standardized rates are used in order to eliminate from observed geographical disparities the part due to differences in the age distribution of the populations compared.

This desire to eliminate from the comparison of mortality levels the part due to differences in age composition of populations is easily justified. It is well known that the age pyramid for a given population is basically determined by past developments in natality and migration which have affected it, and not by past trends in mortality. Differences in composition between populations represent factors of variation which are exogenous to mortality per se. Development of standardized rates is thus one way of developing specific descriptors of mortality conditions prevailing at various ages in the populations being compared.

Figure 13

Crude and Standardized Death Rates, Canada, 1921-1982



Source: Table 25.

However, the information provided by these standardized rates is **relative**. The value of the rates depends on the age composition of the standard population chosen and thus varies with the choice of a standard population. As a general rule, the order in which the mortality rates compared are classified will, nevertheless, be basically the same whatever the chosen standard. The standardized rate is thus only a tool which makes it possible to classify mortality levels in relation to one another.

The Standardized Rate as a Health Indicator

In discussing the crude death rate (see I-01), the possibility was mentioned of assigning a health score to each of the individual members of the population concerned. If m_x is taken as the mean score obtained by members of age group x, and p_x the proportion of persons in that age group, the actual mean health level of the total population could be written:

$$M = \sum_x m_x \cdot p_x$$

This actual mean health level varies over time due to two factors:

- variations in mean health of the various age groups,
- changes in the age composition of the population.

Health policy may influence the direction taken by the first factor, but not that of the second. The health planner thus needs an indicator that will give the trend in mean health after exclusion of effects due to changes in the age composition of the population.

TABLE 25. Crude and Standardized Death Rates, Both Sexes, Canada, 1921-1982

Year	Crude rate[1] (1)	Standardized rate[2] (2)	Ratio (3) = (1)/(2)
	per 1,000		
1921	11.6	12.9	0.90
1922	11.6	13.0	0.89
1923	11.8	13.2	0.89
1924	10.9	12.2	0.89
1925	10.7	12.1	0.88
1926	11.4	13.9	0.82
1927	11.0	13.3	0.83
1928	11.2	13.5	0.83
1929	11.4	13.8	0.83
1930	10.8	13.0	0.83
1931	10.2	12.2	0.84
1932	10.0	12.1	0.83
1933	9.7	11.6	0.84
1934	9.5	11.4	0.83
1935	9.9	11.6	0.85
1936	9.9	11.5	0.86
1937	10.4	12.1	0.86
1938	9.7	11.1	0.87
1939	9.7	11.1	0.87
1940	9.8	11.0	0.89
1941	10.1	11.2	0.90
1942	9.8	10.7	0.92
1943	10.1	11.0	0.92
1944	9.8	10.5	0.93
1945	9.5	10.1	0.94
1946	9.4	9.9	0.95
1947	9.4	9.7	0.97
1948	9.3	9.5	0.98
1949	9.3	9.4	0.99
1950	9.1	9.1	1.00
1951	9.0	9.0	1.00
1952	8.7	8.8	0.99
1953	8.6	8.6	1.00
1954	8.2	8.2	1.00
1955	8.2	8.2	1.00
1956	8.2	8.2	1.00
1957	8.2	8.3	0.99
1958	7.9	8.0	0.99
1959	8.0	8.0	1.00
1960	7.8	7.8	1.00
1961	7.7	7.6	1.01
1962	7.7	7.6	1.01
1963	7.8	7.6	1.03
1964	7.6	7.3	1.04
1965	7.6	7.3	1.04
1966	7.5	7.2	1.04
1967	7.4	7.1	1.04
1968	7.4	7.1	1.04
1969	7.4	7.0	1.06
1970	7.3	6.9	1.06
1971	7.3	6.7	1.09
1972	7.4	6.8	1.09
1973	7.4	6.8	1.09
1974	7.4	6.8	1.09
1975	7.3	6.5	1.12
1976	7.3	6.4	1.14
1977	7.2	6.3	1.14
1978	7.2	6.2	1.16
1979	7.1	5.9	1.20
1980	7.2	5.8	1.24
1981	7.0	5.6	1.25
1982	7.1	5.5	1.29

[1] Excludes Yukon and Northwest Territories from 1921 to 1923, and Newfoundland from 1921 to 1948; includes Quebec from 1921.

[2] Excludes Quebec from 1921 to 1925, Newfoundland prior to 1949, Yukon and Northwest Territories prior to 1950.

Source: Crude rates for the period 1921-1949 are taken from Leacy, F.H. (Ed.), **op. cit.**, Series B18. All other rates are taken from Statistics Canada, **Vital Statistics**, Catalogue 84-206 (1977) and Catalogue 84-204 (1978 to 1982).

To obtain an indicator of trends of "intrinsic mean health", one might envisage an annual calculation of the mean of quantities m_x, always weighting them using the same coefficients p_x. One would then use a method of calculation exactly identical to that used to obtain standardized death rates.

In fact, quantities m_x are normally unknown. However, it has been seen that these could reasonably be replaced by the death rates at the same ages in order to obtain a substitute indicator (see I-01). Consequently, the standardized death rate may be used as an indicator of the relative level of intrinsic mean health of a population.

Based on this interpretation, standardized rates could be used to rapidly identify sub-populations whose health status might be improved by increased or better-adapted monitoring of health conditions.

III TECHNICAL DISCUSSION

Calculating a Standardized Rate

The principle by which this rate is calculated may be illustrated using a purposely limited body of statistical data. Table 26 shows the age-specific death rates for Canada in 1981, as well as the age composition of the Canadian population at the 1956 census. By multiplying the population groups by the appropriate death rate, one obtains for each age what is obviously a fictitious number of deaths. These are the deaths that would have been recorded in 1956 if the Canadian population had been subjected to the mortality observed 25 years later. The ratio of the sum of these fictitious deaths to the total size of the population gives a standardized rate, the significance of which still must be explained.

TABLE 26. Calculation of a Standardized Rate (simplified example), Canada, 1981

Age group	Death rates in 1981 (per 1,000)	Size of population in 1956	Deaths calculated	Standardized rate (per 1,000)
	(1)	(2)	(3) = (1)x(2)	(4) = (3)/(2)
0-14 years	1.0	5,225,210	5,225	
15-64 "	3.1	9,611,643	29,796	
65 years and over	48.5	1,243,938	60,331	
Total		**16,080,791**	**95,352**	**5.9**

Source: Statistics Canada, **1956 Census of Canada,** Vol. I, Table 21 and Statistics Canada, **Vital Statistics 1981,** Catalogue 84-204, Table 18.

The number of data entries in Table 26 is sufficiently limited to enable the reader to easily determine that the standardized rate is nothing more than the weighted average of the age-specific death rates for the year 1981. These calculations give the same result as would calculating this mean by attributing to each age-specific rate a weight equal to the relative size of the corresponding age group in the Canadian population in 1956. The standardized rate thus gives the number of deaths per 1,000 that would have been recorded in Canada in 1981 if the age composition of the population had been the same as in 1956.

In the example presented above, only a division of the population into children, adults and elderly persons has been retained, for explanatory purposes. It is clear that, in normal statistical practice, a finer division by age would be used, generally some 20 different groups. Other structural effects than that of age composition might also be eliminated by introducing additional variables, notably the sex distribution.

Choosing the Standard Population

A standard population is generally chosen out of habit, practicality or common sense. For comparisons over time, the Canadian population used is generally that of 1956, and the American population is that of 1940. In comparing regions, the standard is very often the national population, as was the case in a recent study on the geography of mortality in Canada.[3] In other circumstances, for example when comparing several countries, the choice of a standard population would certainly appear to be more arbitrary.

The important question is obviously whether the ranking of the mortality rates being compared depends on the standard chosen. This is clearly the case. For example, a study of mortality in the 50 American states in 1968 showed that 21 states were ranked differently depending on whether the standard used was the 1940 population or that of 1970.[4] This study also showed, however, that rank varied by only one point in the majority of cases. It may then be concluded that, in practice, ranking different mortality rates using one given standard population is normally reliable, provided one does not expect this method to discriminate correctly between very similar mortality rates.

It should also be mentioned that a complex statistical procedure known as principal components analysis can be used to select the optimal standard population, i.e. the one that will give the best possible ranking of standardized rates.[5]

The Case of Small Populations

Age-specific death rates of small populations are characterized by wide random fluctuations, and these have a noticeable effect on the value of standardized rates. For this reason, differences observed between standardized rates are not always significant. To determine the significance of such differences, it is necessary to use indices developed for this purpose by statisticians.[6]

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3 Canada. Health and Welfare Canada and Statistics Canada, **Mortality Atlas of Canada,** Vol. 2, Supply and Services Canada, Ottawa, 1980.

4 Metropolitan Life Insurance, "Standardized Mortality Rates", **Statistical Bulletin,** 62, 2, 1981, pp. 5-14.

5 Duchêne, J. and Wunsch, G., **Population-type optimale et composante principale** (Working Paper No. 87), Département de démographie, Université catholique de Louvain, 1980, 8 p.

6 W.H.O., **Manual of Mortality Analysis** (Reprint), Geneva, W.H.O., 1980, 245 p.

I-03: LIFE EXPECTANCY AT BIRTH (PERIOD APPROACH)

I DESCRIPTION

Definition

Mean length of life, assuming mortality is stabilized at the level observed at each age during a year or a given period.

Descriptive Function

The calculation implicitly assumes that members of a cohort are subjected, throughout their lives, to risks of death calculated on the basis of observations made during a year or other period. The mean length of life of members of this synthetic cohort depends only on observed mortality conditions. This provides a highly significant and specific descriptor of the mortality prevailing throughout the life cycle.

Indication Sought

This would be an indication of the level of intrinsic mean health of the population. It is assumed that this level is positively correlated to life expectancy at birth.

II INTERPRETATION

The Descriptor

Mortality recorded during a year or other period may be summarized in other ways than by the annual frequency of death in the population. Calculations (see technical discussion) make it possible to determine how the size of a cohort would decrease from one age to another if the members were hypothetically subject, throughout their lives, to the risks of death which are characteristic of the mortality observed. Thus the mortality of a period is described by means of its calculable effects on the fate of an obviously synthetic cohort. In this way, one obtains a group of particularly sensitive descriptors, the best known of which is life expectancy at birth.

These life tables based on synthetic cohorts are called "period" tables to distinguish them from life tables for real cohorts (cohort or generation life tables). In Canada, such period tables are drawn up regularly, based on mortality observed during the three-year period centered on census years. This series of tables is relatively short, however, since the oldest covers the period 1930-32. Nevertheless it is possible to go further back in time using tables recently drawn up by Bourbeau and Légaré (**op. cit.**) to illustrate probable levels of mortality at the beginning of each decade of the 1831-1931 period. It is from the body of data on mortality in Canada during the period 1831-1981 that will be extracted those elements necessary for a proper interpretation of life expectancy at birth and how it evolves over time.

Table 27 shows, for a group of 1,000 persons at birth, the number of persons of each sex still alive at various birthdays in the synthetic cohorts respectively subjected to mortality conditions prevalent around 1831, 1881, 1931 and 1981. Over 150 years, the chances of reaching early adulthood (age 15) rose from 66 to 98% for males and from 68 to 99% for females, while chances of reaching old age (age 65) increased from 27 to 75% for men and from 30 to 86% for women. This is a striking illustration of the impact of a decline in mortality on the lives of individuals: once the privilege of a minority, the possibility of living through all the stages of a complete life cycle is now open to the majority.

Figure 14 gives a clear picture of this democratization of life. Following along the y-axis, it can be seen that a given probability of survival is attached to increasingly advanced ages as one progresses from the older to the more recent mortality conditions. Thus the **median length of life**, or the age reached by 50% of the members of a cohort, would have remained under 50 years if mortality had not declined since the middle of the 19th century, while it would rise to 75 years for men and 82 years for women if 1981 mortality conditions were to persist.

TABLE 27. Survivorship Functions, Canada 1831-1981

Exact age	Around 1831		Around 1881		1930-32		1980-82	
	Males	Females	Males	Females	Males	Females	Males	Females
0 years	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
1 year	814	838	835	857	913	931	989	992
5 years	704	724	751	772	890	910	987	990
10 "	678	695	730	750	881	902	985	989
15 "	663	677	717	736	874	895	983	988
20 "	640	650	698	716	863	885	977	985
25 "	608	616	672	690	849	870	970	983
30 "	577	582	646	663	834	854	963	980
35 "	545	548	619	635	820	836	956	977
40 "	509	514	589	606	802	816	948	972
45 "	472	480	554	576	780	794	935	965
50 "	431	446	514	544	752	768	914	952
55 "	384	407	466	505	713	733	879	933
60 "	329	360	408	456	659	684	825	904
65 "	266	302	338	391	587	617	747	861
70 "	197	233	256	311	489	526	640	797
75 "	126	156	169	216	366	407	504	705
80 "	65	87	91	124	229	265	350	575
85 "	25	37	36	53	110	133	200	406

Source: Bourbeau,R. and Légaré, J., **Évolution de la mortalité au Canada et au Québec, 1831-1931**, Montreal, Presses de l'Université de Montréal, 1982, pp. 77 and 82; Dominion Bureau of Statistics, **Life Tables for Canada and Regions, 1941 and 1931**, Catalogue 84-515, Ottawa, 1947; Statistics Canada, **Life Tables, Canada and Provinces, 1980-1982,** Catalogue 84-532, pp. 16-19.

This increase in the chances of living a complete life is also illustrated by a tremendous increase in life expectancy at birth, i.e. the average duration of life in given mortality conditions. The mortality level of the Canadian population around 1831 allowed a mean length of life of only 39 years for persons of both sexes, while the 1981 level makes possible a mean length of 75.3 years (Table 28). As Figure 15 shows, the upward trend in life expectancy at birth was most striking during the period 1891-1951.

To get a more tangible idea of the relationship between changing patterns in mortality and the increase in life expectancy at birth, one may calculate how variations in the risk of death at various ages have contributed to this increase. As demonstrated in the technical discussion, each contribution depends on:

(a) the absolute value of the variation in risk of death at a given age, and whether this value is positive or negative,

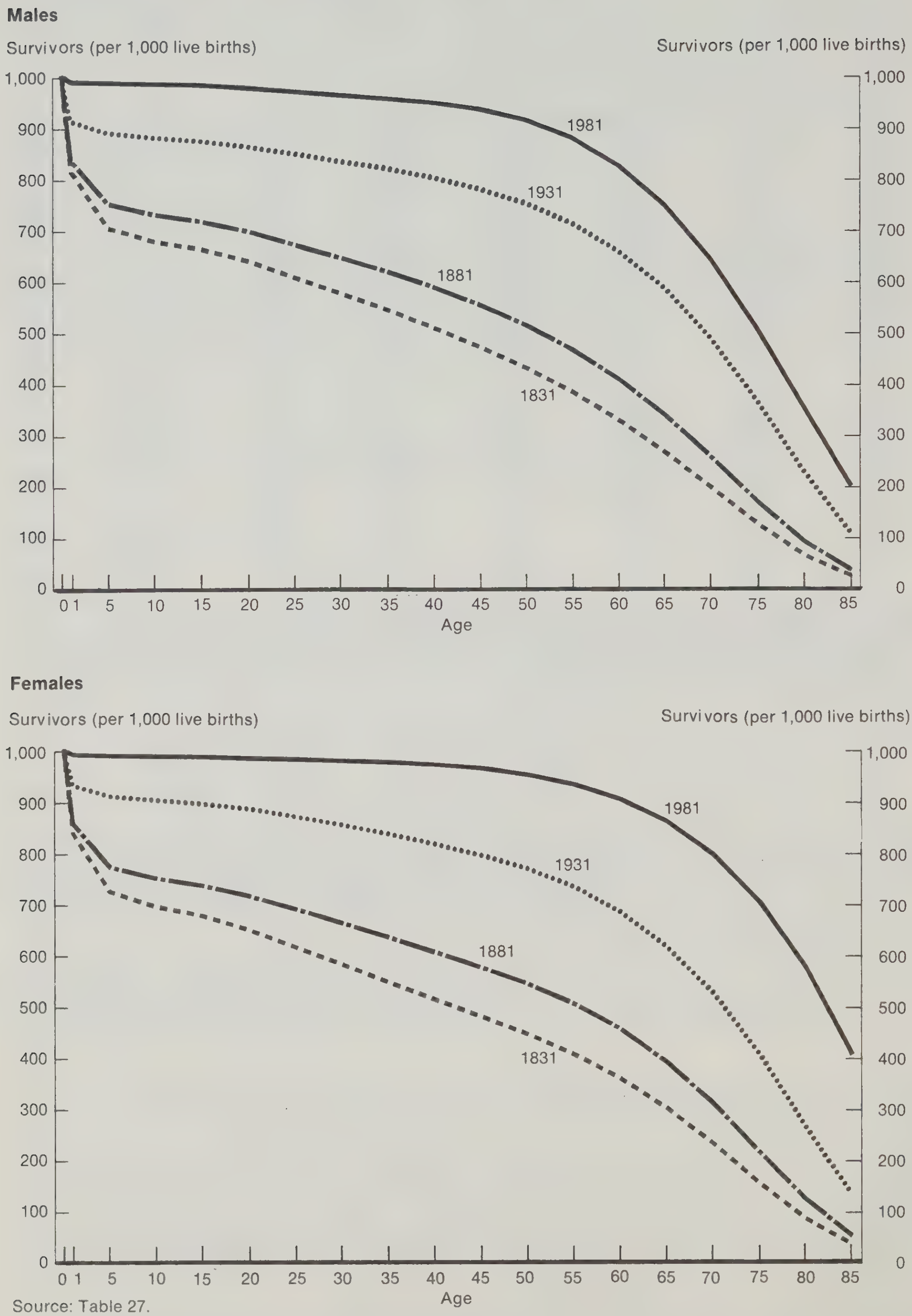
(b) the proportion of members of the synthetic cohort who are still alive at that age and who consequently benefit or suffer from this change in mortality,

(c) the average number of years of life gained per death avoided or, as the case may be, lost per additional death at the age considered.

The necessary calculations were made for the period covered by life tables published to date by Statistics Canada, i.e. 1931-1981. The contributions obtained to life expectancy at birth, whether positive or negative, are shown in Table 29, with Figure 16 showing the 50-year totals.

Figure 14

Survivorship Curve, by Sex, Canada, 1831-1981



Source: Table 27.

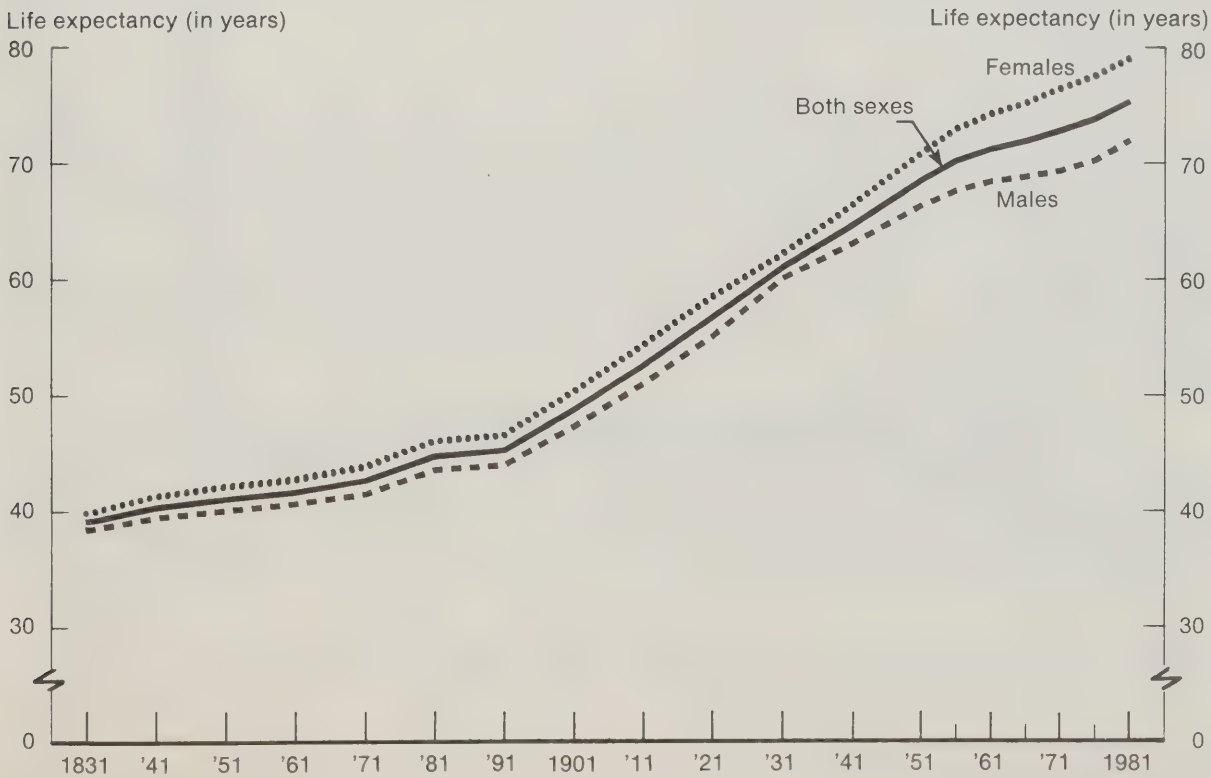
TABLE 28. Life Expectancy at Birth by Sex, Canada, 1831-1981

Period	Male	Female	Both sexes
		years	
Around 1831	38.3	39.8	39.0
Around 1841	39.4	41.3	40.3
Around 1851	40.0	42.1	41.0
Around 1861	40.6	42.7	41.6
Around 1871	41.4	43.8	42.6
Around 1881	43.5	46.0	44.7
Around 1891	43.9	46.5	45.2
Around 1901	47.2	50.2	48.7
Around 1911	50.9	54.2	52.5
Around 1921	55.0	58.4	56.7
1930-32	60.0	62.1	61.0
1940-42	63.0	66.3	64.6
1950-52	66.3	70.8	68.5
1955-57	67.6	72.9	70.2
1960-62	68.4	74.2	71.2
1965-67	68.8	75.2	71.9
1970-72	69.3	76.4	72.8
1975-77	70.2	77.5	73.8
1980-82	71.9	79.0	75.3

Source: Prior to 1930-32: Bourbeau, R. and Légaré, J., **op. cit**, pp. 77-86; 1930-32 to 1975-77: Statistics Canada, **Vital Statistics 1977**, Vol. III: Deaths, Catalogue 84-206, p. 2; 1980-82: Statistics Canada, **Life Tables, Canada and Provinces, 1980-82**, Catalogue 84-532, May 1984, pp. 16 and 18.

Figure 15

Life Expectancy at Birth, by Sex, Canada, 1831-1981



Source: Table 28.

The most striking result of this calculation is the great contribution made by reduction of risks of death in early childhood. Further, the most important element is the decline in mortality before the first birthday. This is easily explained by the fact that the young lives thus spared in a given cohort were more numerous than those spared in the following ages, and that, the younger the child, the greater the average number of years of life gained per death avoided. Continual lowering of the level of infant mortality does, however, constantly reduce the number of deaths that could possibly be avoided in these 12 months following birth, as well as the associated gain in mean length of life. This declining gain in longevity associated with improved survivorship in the first year of life is already perceptible in Table 29. It will also necessarily continue into the future, since the complete elimination of the risk of death before age one would only increase life expectancy at birth by 0.79 years for boys and 0.67 years for girls.[7] It may be concluded that the decline in infant mortality is no longer a significant source of increase in life expectancy (see Figure 17).

The second notable point is the difference between the sexes with respect to the size of contributions due to gains during adulthood or old age. This difference also exists in childhood, but its relative value is slighter and in favour of males. Once childhood is past, it is females who constantly benefit from the largest contributions, and these can be two to four times higher than those calculated for males. It is thus in the development of excess male mortality in adulthood and old age that one must seek the origins of the widening of the gap between the mean length of life of men and women.

Based on this brief analysis, one can now better judge the validity of the principal objection to the use of life expectancy at birth as a descriptor of mortality, i.e. its over-sensitivity to changes in infant mortality. This appears indisputable by looking only at data on the life expectancy of males: close to half the increase between 1931 and 1981 may be attributed to the decrease in the number of deaths to children under one year of age. It is already less convincing by looking at the life expectancy of females, since the same reduction, while producing a longevity gain that is comparable in absolute terms, is only responsible for a quarter of the total increase observed during the same period. Finally, this argument could not be used to explain the widening of the gap between the mean length of life of males and females. While it is true that life expectancy at birth is sensitive to changes in infant mortality, it is far from being a descriptor of this alone. This means that the objection discussed above is less to the measuring tool used than to the phenomenon measured. If a substantial decrease in the risk of death in adulthood or old age were to occur tomorrow, life expectancy at birth would change to reflect this, and this reflection would be all the more faithful since any gains in length of life that would still be possible through the reduction of infant mortality are necessarily very limited.

The Indicator

Being able to offer a growing number of people the possibility of living through all the stages of a complete life cycle has been unanimously accepted as a valid social concern for several decades. Some recent texts which propose that the policy of lengthening human life be abandoned might lead one to believe that this is no longer the case. What is being questioned here, however, is the obligation imposed on doctors to attempt to prevent death even in cases where the survivor would spend remaining years in conditions judged unacceptable from a human standpoint. No one denies that it is still necessary to combat the causes of premature death, nor that social inequality in the face of death should be reduced to ensure the best chances of survival to all. It is clear that these two specific objectives stem from the social concern expressed above, and that this concern is still alive today.

Life expectancy at birth provides a good reflection of the extent to which this concern is being satisfied. Its value depends simply on the set of probabilities of survival from birth to various ages, and any increase in this value over time has essentially resulted from a reduction in the risk of death among children and adults. The indication provided is **prospective** in the sense that the mean length of life calculated has not been achieved at the time of observation, but will be attained in the long term if mortality remains at the level observed.

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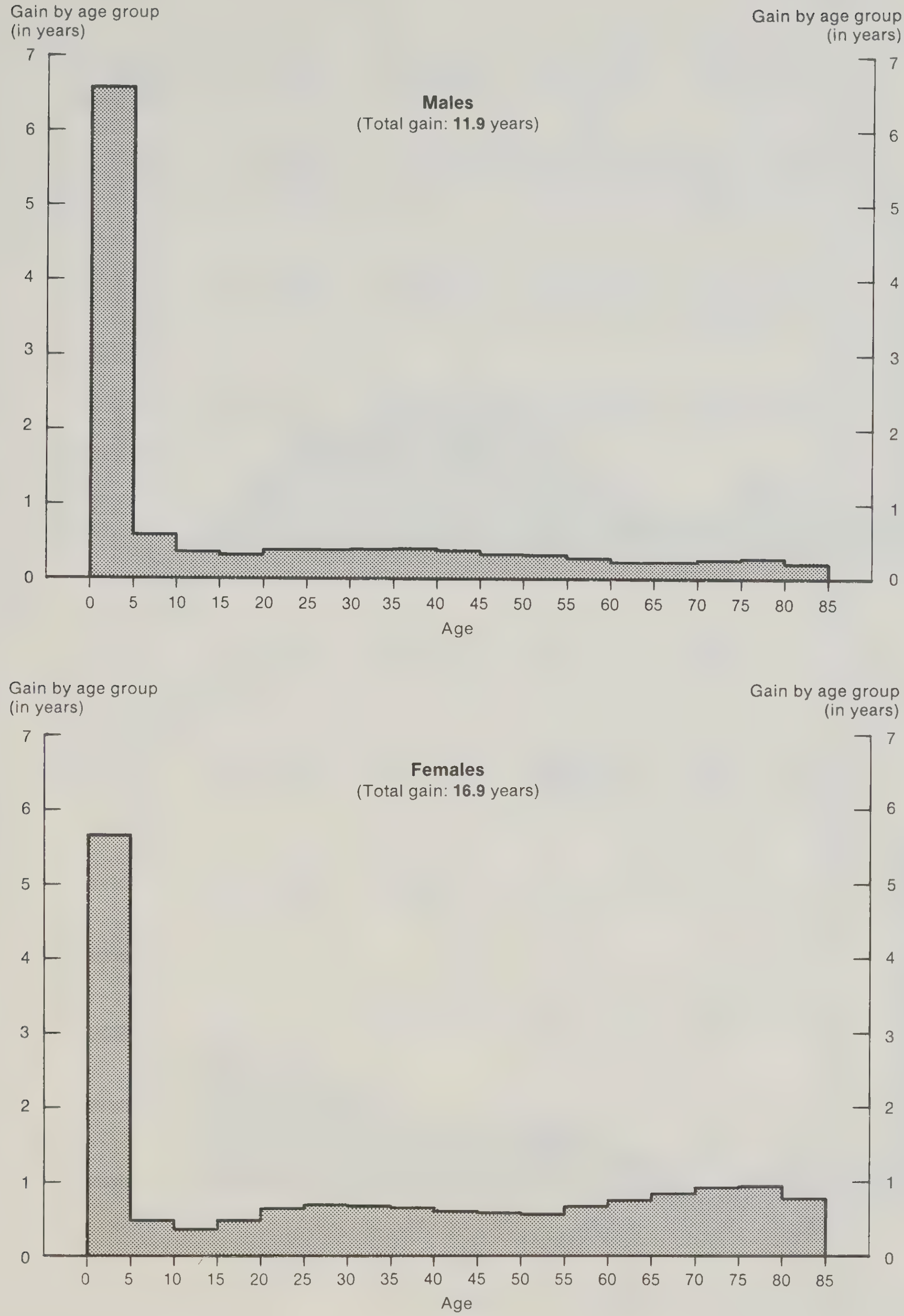
7 A similar calculation for the 1930-32 life table shows a gain of 5.69 years for boys and 4.61 for girls.

Figure 16

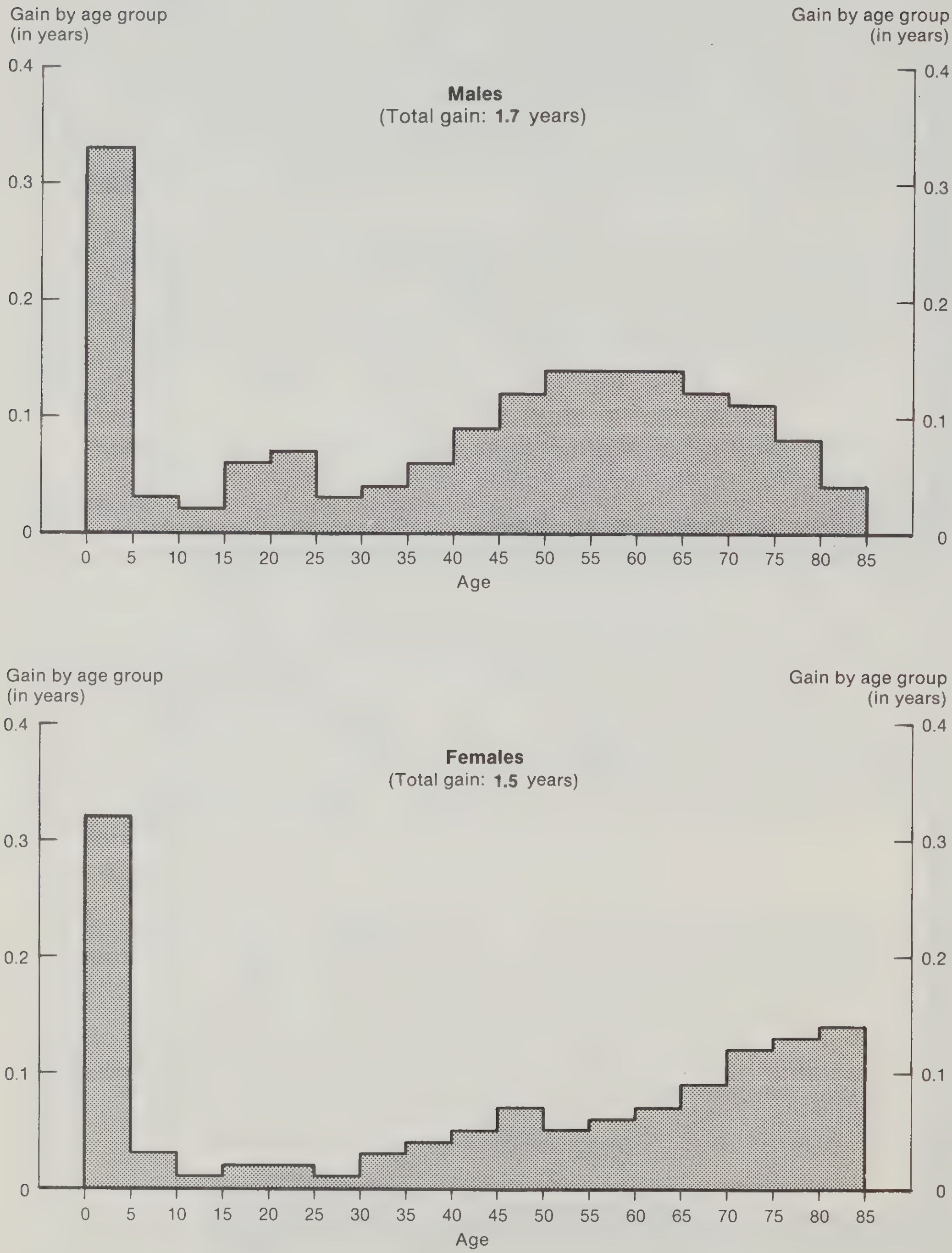
Gains in Life Expectancy at Birth Due to Mortality Decrease at Various Ages, by Sex, Canada, 1931-1981



Source: Table 29.

Figure 17

Gains in Life Expectancy at Birth Due to Mortality Decrease at Various Ages, by Sex, Canada, 1976-1981



Source: Calculated from Statistics Canada, Life Tables, Canada and Provinces, Catalogue 84-532 (1975-1977 and 1980-1982).

TABLE 29. Gains in Life Expectancy at Birth Due to Mortality Decrease at Various Ages, by Sex, Canada, 1931-1981

Age interval (in years)	Period											
	1931-1941		1941-1951		1951-1961		1961-1971		1971-1981		1931-1981	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
	in years											
0- 1	1.60	1.33	1.27	1.05	0.89	0.75	0.74	0.63	0.66	0.55	5.16	4.31
1- 5	0.51	0.51	0.54	0.49	0.20	0.19	0.07	0.06	0.09	0.09	1.41	1.34
5-10	0.17	0.16	0.19	0.17	0.10	0.08	0.04	0.02	0.07	0.04	0.57	0.47
10-15	0.09	0.15	0.12	0.11	0.06	0.07	0.02	- 0.01	0.05	0.03	0.34	0.35
15-20	0.12	0.21	0.14	0.18	0.06	0.08	- 0.07	- 0.02	0.05	0.03	0.30	0.48
20-25	0.16	0.27	0.17	0.24	0.04	0.11	- 0.05	- 0.01	0.06	0.03	0.38	0.64
25-30	0.15	0.28	0.15	0.28	0.07	0.09	- 0.01	0.01	0.02	0.03	0.38	0.69
30-35	0.13	0.24	0.13	0.26	0.08	0.10	- 0.01	0.01	0.06	0.05	0.39	0.66
35-40	0.12	0.20	0.15	0.23	0.05	0.13	0.01	0.00	0.07	0.08	0.40	0.64
40-45	0.06	0.16	0.12	0.18	0.07	0.15	- 0.01	0.01	0.12	0.09	0.36	0.59
45-50	0.03	0.13	0.06	0.15	0.07	0.17	0.02	0.04	0.13	0.08	0.31	0.57
50-55	0.00	0.09	0.02	0.17	0.09	0.15	0.01	0.04	0.18	0.10	0.30	0.55
55-60	- 0.02	0.11	- 0.01	0.19	0.05	0.17	0.06	0.08	0.18	0.12	0.26	0.67
60-65	- 0.06	0.11	- 0.01	0.16	0.04	0.20	0.04	0.15	0.20	0.13	0.21	0.75
65-70	- 0.04	0.07	0.07	0.21	0.00	0.19	0.00	0.20	0.19	0.17	0.22	0.84
70-75	- 0.03	0.08	0.09	0.17	0.01	0.24	0.02	0.21	0.16	0.22	0.25	0.92
75-80	- 0.02	0.06	0.09	0.16	0.05	0.22	0.04	0.25	0.11	0.25	0.27	0.94
80-85	- 0.01	0.04	0.05	0.09	0.06	0.15	0.04	0.24	0.05	0.24	0.19	0.76
All ages	**2.96**	**4.20**	**3.37**	**4.53**	**2.02**	**3.34**	**0.99**	**2.19**	**2.54**	**2.62**	**11.88**	**16.88**

Source: Nguyen, V.C., **La longévité moyenne des hommes et des femmes au Canada de 1931 à 1976**, M.Sc. thesis, Department of demography, Université de Montréal, December 1980; and calculations based on Statistics Canada, **Life Tables, Canada and the Provinces**, Catalogue 84-532 (1975-1977 and 1980-1982).

The important question here is obviously whether an increase in life expectancy at birth reflects an improvement in the health of the population. Considering the secular trend, the answer is certainly in the affirmative, since "life expectancy in good health" today is greater than the total mean length of life allowed by the mortality conditions of a few decades ago (see I-04). One may wonder whether the reply would still be positive in the light of the more recent trends.

At the time when life expectancy at birth was still progressing rapidly in all developed countries, it was unanimously considered a good indicator of health level. It was quite clear that the decline in communicable diseases, which had been predominant up to then, was accompanied by both an improvement in health and a decrease in mortality among children and young adults. In addition, since all this progress was generously attributed to better health protection of the population and to the growing effectiveness of prevention and curative care, trends in life expectancy at birth provided an evaluation of the saliency of decisions made in the health field.

In such a context, the increasingly pronounced slowdown of this rise in mean length of life from the 1950s on necessarily caused great consternation.[8] At the time, this slowdown was interpreted as a prelude to an imminent and inevitable stabilization of mean longevity. According to this scenario, any future improvements in the health of developed populations would no longer be translated as gains in their mean length of life. As this limit was approached, life expectancy at birth would gradually lose its sensitivity and its ability to act as a health indicator.

Contrary to any expectation, life expectancy at birth then began to rise sharply in the United States. The increase for both sexes was 4.3 years between 1968 and 1982, while it had been only 0.6 years between 1954 and 1968 (Table 30). This unexpected reversal in the trend of course led to a new interpretation of the slowdown in the progression of the indicator during the preceding period.

This slowdown now appears to have been a faithful reflection of a growing but temporary difficulty in improving the health of the population, in particular that of adults and the elderly.

This difficulty in turn was mainly due to the apparent lack of means for controlling the constant increase in morbidity and mortality attributable to many highly disabling and lethal chronic illnesses. It was not known why these diseases had become so common, nor how they could effectively be treated. Research in these two areas was not undertaken in vain, as witness the American experience. Starting in the mid-1960s, public health authorities in the United States began to caution the population to limit its exposure to the risk factors that had been identified: cigarette smoking, consumption of animal fats, sedentary habits, etc. The result was an increasingly far-reaching change in the American lifestyle.[9] Bearing in mind knowledge already acquired in the field of epidemiology, it would be very surprising if such a change did not have a beneficial effect on the health of the population. Without excluding the probable contribution of indisputable progress in therapy, this change in lifestyle is generally held to have played a leading role in the subsequent drop in mortality. It seems quite likely that recent increases in life expectancy at birth reflect the appearance of new possibilities for improving the health of the population by limiting the exposure of individuals to the risk factors of diseases of adulthood and old age.

As in the past, life expectancy at birth thus remains a good indicator of the health level of the population. This is of course the intrinsic mean health, since the effect of a change in the age composition of the population is not taken into consideration.

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8 It is nonetheless important to note that, contrary to what one might believe, the decrease in the gains of average life expectancy does not, in itself, imply the interruption of progress in the fight against mortality. The continuation of a constant progress in life expectancy at birth requires, in effect, not only the continuation of the mortality decline, but its acceleration.

9 Walker, W.J., "Changing United States Life-Style and Declining Vascular Mortality: Cause or Coincidence?", **New England Journal of Medicine**, Vol. 297, 3, July 21, 1977, pp. 163-165, and Rowland, M. and Kleinman, J., "Changes in Heart Disease Risk Factors" in United States. NCHS, **Health United States 1983**, Washington, D.C., U.S. Government Printing Office, December 1983, pp. 13-17.

TABLE 30. Life Expectancy Trends by Sex, United States, 1946-1982

Year	Males	Females	Both sexes
		years	
1946	64.4	69.4	66.7
1947	64.4	69.7	66.8
1948	64.6	69.9	67.2
1949	65.2	70.7	68.0
1950	65.6	71.1	68.2
1951	65.6	71.4	68.4
1952	65.8	71.6	68.6
1953	66.0	72.0	68.8
1954	66.7	72.8	69.6
1955	66.7	72.8	69.6
1956	66.7	72.9	69.7
1957	66.4	72.7	69.5
1958	66.6	72.9	69.6
1959	66.8	73.2	69.9
1960	66.6	73.1	69.7
1961	67.1	73.6	70.2
1962	66.9	73.5	70.1
1963	66.6	73.4	69.9
1964	66.8	73.7	70.2
1965	66.8	73.8	70.2
1966	66.7	73.9	70.2
1967	67.0	74.3	70.5
1968	66.6	74.1	70.2
1969	66.8	74.4	70.5
1970	67.1	74.7	70.8
1971	67.4	75.0	71.1
1972	67.4	75.1	71.2
1973	67.6	75.3	71.4
1974	68.2	75.9	72.0
1975	68.8	76.6	72.6
1976	69.1	76.8	72.9
1977	69.5	77.2	73.3
1978	69.6	77.3	73.5
1979	70.0	77.8	73.9
1980	70.0	77.5	73.7
1981[1]	70.3	77.9	74.1
1982[1]	70.8	78.2	74.5

[1] Preliminary data.

Source: 1946-1980: United States. National Centre for Health Statistics. **Vital Statistics of the United States, 1980, Vol. II, Sec. 6, Life Tables**. D.H.H.S. Pub. No. (PHS) 84-1104. Public Health Service, Washington, D.C., U.S. Government Printing Office, 1984, Table 6-5, p. 16; 1981-1982: United States. National Center for Health Statistics. **Health United United States 1983**, DHHS Pub. No. (PHS) 84-1232. Public Health Service. Washington, D.C., U.S. Government Printing Office, December 1983, Table 10, p. 99.

III TECHNICAL DISCUSSION

Age-specific Death Rates and Probabilities

The age-specific mortality profile during a given calendar year may be illustrated by a series of rates or a series of probabilities. The death rate at a given age x is the ratio of the number of deaths D_x recorded at this age to the number of persons P_x in age group x at mid-year:

$$M_x = D_x/P_x$$

Increasing the denominator of this rate by a quantity equal to half the number of deaths, one obtains the annual probability of death at age x:

$$Q_x = D_x/(P_x + \tfrac{1}{2} D_x)$$

Statistics available in Canada permit the calculation of these two indices provided one substitutes for P_x the corresponding figures from population estimates as of June 1.

Unlike a rate, an annual probability of death is an estimate of the risk of death between birthdays x and x + 1 for persons still alive on the first of these birthdays. This is easily understood if considered in the context of the history of a cohort.

Suppose for example that the following information is known about women born in 1950:

- number of women present in the country at the time of their 30th birthday (V) and the size of the same group on January 1, 1981 (P),
- number of women who, between their 30th and 31st birthdays, died in the country (D), left the country (E) or arrived from another country (I).

Applying to the number V an average probability Q of dying in the 12 months following their 30th birthday, one obtains VQ, or the number of probable deaths before the next birthday. These probable deaths are not equal to the number of deaths observed in the country because of migrations. Assuming that arrivals and departures occur on the average in the middle of the age interval considered, one may estimate that $\tfrac{1}{2}$EQ deaths may not be recorded in the country due to emigration, but that immigration will add $\tfrac{1}{2}$IQ additional deaths. The relationship between observed deaths and expected deaths may be written as follows:

$$D = VQ - \tfrac{1}{2}EQ + \tfrac{1}{2}IQ$$

To calculate the value of probability Q, the number of observed deaths is simply divided by V reduced by half of the departures and increased by half of the arrivals. If all these events (deaths, departures, arrivals) are equally spread out between 1980 and 1981, the denominator of this risk is equal to P increased by half of the deaths, since one would then have:

$$P = V - \tfrac{1}{2}D - \tfrac{1}{2}E + \tfrac{1}{2}I$$

Risk Q may then be obtained as:

$$Q = D/(P + \tfrac{1}{2}D)$$

Since on January 1, 1981, women born in 1950 are all between the ages of 30 and 31 exactly, P is the size of the cohort at the date when it forms the age category "30 (complete) years". In other words, the risk of death for a cohort during the 12 months following birthday x may be calculated by taking the ratio of the deaths observed before the following birthday to the sum of half of these deaths and the number of members of the cohort at the time it forms age group x.

To use the same formula to calculate death probabilities for a calendar year, one simply takes for the deaths observed at age x those deaths which would be counted at that age in the cohort forming age group x at mid-year. For very early ages, this formula must be adjusted to take into account lack of symmetry in the distribution of deaths between two successive birthdays.

Period Life Table

Using age-specific probabilities of death, mortality conditions prevailing in a given year or period are illustrated by a series of risks of death between successive birthdays. It is then possible to simulate the history of a cohort whose members would hypothetically be subject throughout their lives to these risks of death. Mortality conditions will thus be perceived by means of their consequences on the fate of a synthetic cohort and not in terms of the annual number of deaths in a population.

The calculation is made for intervals of one year, from birth to the last age, i.e. complete extinction of the cohort. Using Table 31, it may be seen that this progressive calculation starts as follows:

$$D_0 = S_0 \cdot Q_0$$
$$S_1 = S_0 - D_0$$
$$D_1 = S_1 \cdot Q_1$$
$$S_2 = S_1 - D_1$$

TABLE 31. Calculation of a Life Table, Canadian Women, 1940-42

Exact age x	Probability Q_x	Survivors S_x	Deaths D_x	Fraction f_x	Years lived A_x	Cumulated years T_x	Life expectancy e_x
0 years	0.04931	100,000	4,931	0.212	96,113	6,629,807	66.30
1 year	0.00634	95,069	603	0.500	94,768	6,533,694	68.73
2 years	0.00326	94,466	308	0.500	94,312	6,438,926	68.16
3 "	0.00262	94,158	247	0.500	94,034	6,344,614	67.38
4 "	0.00194	93,911	182	0.500	93,820	6,250,580	66.56

Source: D.B.S., **Life Tables for Canada and Regions, 1941 and 1931**, Catalogue 84-515, Ottawa, 1947, p. 9.

It is clear that, once the initial size of the cohort has been arbitrarily determined, the deaths and survivors in the table are calculated using only the series of age-specific probabilities of death.

Years Lived and Life Expectancy

Knowing the deaths and survivors from the table enables one to calculate the number of years lived by members of the synthetic cohort. Between birthdays x and x + 1, this number equals:

$$A_x = S_{x+1} + f \cdot D_x$$

Survivors at birthday x+1 necessarily live one complete year in this age interval, while those deceased live on the average only a certain fraction f. This fraction f is quite close to 0.5 except for advanced ages and during the first year of life.

Once the number of years lived in the various age intervals has been calculated, they are cumulated working backwards from the last age to birth. The totals T_x of the years lived after the various birthdays x are thus obtained.

Since the years lived after birthday x can only be lived by those surviving on that birthday, the totals T_x are divided by survivors S_x to obtain the average number of years still left to live by survivors on birthday x, or **life expectancy at exact age x.**

Life expectancy at birth is obviously of particular interest since it provides the average duration of life permitted by observed mortality conditions. It also makes it possible to determine, at any time, what would be the mean length of life of future cohorts if these mortality conditions remained unchanged.

Factors of Change in Life Expectancy at Birth

Any variation in death probabilities over time necessarily brings about a change in the series of deaths and the series of survivors in the table, and consequently the figures derived from these: years lived and life expectancies. The authors propose to examine here what the effect of a variation in mortality at a given age would be on life expectancy at birth, using a method described by Calot and Léry.[10,11]

First, let us assume two series of death probabilities which differ only by the value observed at age **a**: Q_a in one case and Q'_a in the other. The two tables computed using these two series would necessarily have in common the same number of survivors S_a at birthday **a**, and the same life expectancy e_{a+1} at birthday a+1. The number of deaths at age **a** would, however, be S_aQ_a in one table and $S_aQ'_a$ in the other. This difference $S_a(Q_a\text{-}Q'_a)$ in the number of deaths at age **a** will make a difference in the total number of years lived beyond age **a**, and this may be calculated as:

$$S_a(Q_a\text{-}Q'_a)\,(0.5 + e_{a+1})$$

For every death deducted (or added), one gains (or loses) a half-year of life before birthday a+1, and e_{a+1} years after that birthday.

Let us now suppose that our two series of death probabilities also differ by the values obtained at ages lower than **a**. The number of survivors at birthday **a** is no longer the same in the two tables: in one it will still be equal to S_a, but in the other it will now be S'_a. This inevitably introduces an additional effect of the mortality difference at age **a**. This additional effect is $(S'_a\text{-}S_a)$ $(Q_a\text{-}Q'_a)$ for the difference between deaths at age **a**, and thus...

$$(S'_a\text{-}S_a)\,(Q_a\text{-}Q'_a)\,(0.5 + e_{a+1})$$

... for the difference in years lived. In a situation of this type, the total contribution of the variation $(Q_a - Q'_a)$ to the difference in total years lived would thus be:

$$S'_a\,(Q_a\text{-}Q'_a)\,(0.5 + e_{a+1})$$

Then simply divide this quantity by S_0 in order to obtain the contribution of the same variation to the difference between life expectancies at birth.[12]

Thus this provides a formula for calculating the effect of a variation in mortality at a given age **a** on the evolution of life expectancy between two points in time t and t', t' being assumed here as occurring after t. This effect depends on the following:

1. the sign and absolute value of the change in risk of death during the period $(Q_a\text{-}Q'_a)$,
2. the proportion of persons exposed to this change in mortality in the table computed at the end of the period (S'_a/S_0),
3. the average number of years of life gained or lost for each death thus avoided or added, assuming mortality to be constant in the subsequent ages $(0.5 + e_{a+1})$.

To get a more exact picture of the specific contribution of a variation in mortality at age **a**, it is preferable to make the calculations for short periods in order to minimize the quantity $(S'_a\text{-}S_a)$ responsible for the additional effect.

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10 Calot, G. and Léry, A., "La baisse de la mortalité se ralentit depuis 10 ans", **Économie et statistique**, nº 39, November 1972, pp. 3-16.

11 A more detailed method based on the same principle was recently proposed by Arriaga, E., "Measuring and Explaining the Change of Life Expectancies", **Demography**, Vol. 21, 1, February 1984, pp. 83-96.

12 Note that a method involving the same principle, proposed by R. Pressat, allows for the estimation of the contribution of each age group to the difference between men and women in total life expectancy. See Pressat, R., "Perspectives de réduction de la surmortalité masculine dans les pays ayant une faible mortalité", **Meeting on sex differentials in mortality: trends, determinants and consequences**, Canberra, The Australian National University, December 1-7, 1981, 19 p., non-published manuscript.

Overview

In developed countries, the statistics required to compute life tables are regularly published at the national level and are often available at the regional level. These statistics are normally of good quality. When the population is less than a million, however, age-specific death rates or probabilities may be subject to wide random fluctuations. One then attempts to limit the effect of these fluctuations by combining data over several years of observation, working with five-year age groups and adjusting the mortality profile by age using graphic or statistical procedures.[13] While estimating risks of death in this manner is slightly longer and more involved than that used above, calculating the table on the basis of these risks is nevertheless done using the procedure already described.

An examination of this series of calculations clearly shows that life expectancy at birth is a specific descriptor of the level of mortality at the various ages. Its sensitivity to variations in the level of mortality at a given age depends not only on the number of deaths thus postponed or advanced, but also on the average number of years of life gained or lost per death subtracted or added.

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[13] See for example: Zayachkowski, W., **Preparation of Complete Life Tables** (Technical Report No. 4, Health and Welfare Division), Dominion Bureau of Statistics, Ottawa.

I-04: LIFE EXPECTANCY IN GOOD HEALTH

I DESCRIPTION

Definition

Mean duration of life in good health, assuming a stabilization of health and mortality levels observed at various ages during a year or other given period.

Descriptive Function

From the total number of years lived by members of a synthetic cohort subjected to observed mortality conditions, one subtracts those years spent in states of poor health. Life expectancy at birth is thus adjusted to allow for the average number of years lived under the influence of disease or its consequences.

Indication Sought

This would be an indication of the level of mean positive health of the population.

II INTERPRETATION

Good Health and Disability

"Good health" is a notion to which one often refers to in everyday life. People are said to be in good health when they appear to enjoy a certain lasting level of well-being, vitality and resistance to disease. Since this is an eminently desirable state, life expectancy in good health naturally appears to be a particularly attractive and suggestive indicator.

Two methods of evaluation may be used to determine whether individuals are in good health. The first consists in putting them through a certain number of clinical, psychological and physical tests. The second method, which is less direct and less costly, would be to ask them whether, because of the state of their health, they experience any difficulty in the normal performance of their everyday activities. It is this second method which is used in most surveys of large populations.

In such studies, a person in good health is expected to be one who does not require the help of others to carry out the basic activities of life (walking, washing, dressing, etc.), and who is capable of participating in economic and social life with no limitation on principal activity (school attendance, work, housekeeping) or other normal activities (shopping, sports, church attendance, etc.). It is thus the absence of disability which serves as a sign of good health.

As a result, "life expectancy in good health" is generally understood to be disability-free life expectancy. This is obtained by subtracting the number of years lived in a state of disability from the total number of years lived by members of a synthetic cohort (see technical discussion). Since years lived in a disabled state are not necessarily all at the end of life, life expectancy in good health cannot be interpreted simply as the age one can expect to reach without ever suffering from a disability.

Life Expectancy in Good Health in Canada

A study carried out in 1978-79 on the health of Canadians measured the prevalence of disability among non-institutionalized persons.[14] Wilkins and Adams added to the results of this survey the data on long-term stays for health reasons in hospitals or other specialized institutions,

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[14] Canada. Health and Welfare Canada and Statistics Canada, **The Health of Canadians: Report of the Canada Health Survey**, Supply and Services Canada, Ottawa, 1981, 236 p.

thus allowing them to estimate the prevalence of disability in the population as a whole.[15] From these estimates, they derived a disability-free life expectancy for Canada and its principal regions (Table 32).

TABLE 32. Life Expectancy, Disability-free Life Expectancy and Quality-adjusted Life Expectancy, Canada, 1978

Regions	Life expectancy (e_0)		Disability-free life expectancy		Quality-adjusted life expectancy	
	Male	Female	Male	Female	Male	Female
			years			
Atlantic provinces	70.5	78.3	56.7	61.8	64.4	71.2
Quebec	69.7	77.6	60.4	63.1	65.5	71.5
Ontario	71.2	78.4	59.5	63.7	66.1	72.1
Prairie provinces	71.5	78.9	59.4	63.0	66.3	72.1
British Columbia	71.5	78.9	57.4	59.8	65.5	70.9
Canada	**70.8**	**78.3**	**59.2**	**62.8**	**65.8**	**71.7**

Source: Table 3, in Wilkins, R. and Adams, O.B ., **op. cit**,., p. 1078.

It may be seen that stabilization of disability and mortality at levels observed in 1978 would lead to a life expectancy in good health in the order of 63 years for Canadian women and 59 years for Canadian men. In the same conditions, the average number of years lived in poor health would be around 15 for women and around 12 for men. On the average, Canadian males would thus be in poor health for one year out of six and Canadian females one year out of five.

In the present state of research, these values should of course not be considered as absolute measures of good or poor health. On the one hand, the use of restrictions on normal activities as a criterion of disability in the Canadian study no doubt favoured the intrusion of factors exogenous to health status into the evaluation of the phenomenon (see technical discussion); this would not necessarily be the case if one used criteria such as restricted mobility or dependency on others in carrying out the basic activities of daily life.[16] On the other hand, taking into account some short-term disabilities which do not reflect the usual state of health of the individuals concerned, is probably less legitimate in calculating life expectancy in good health than in calculating disability-free life expectancy. These are nevertheless very valuable indications.

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[15] Wilkins, R. and Adams, O.B., "Health Expectancy in Canada, Late 1970s: Demographic, Regional and Social Dimensions", **American Journal of Public Health**, Vol. 73, 9, 1983, pp. 1073-1080.

[16] For an example of how such criteria are used, see: Colvez, A. and Robine, J.W., "L'espérance de vie sans incapacité à 65 ans: outil d'évaluation en santé publique", Paper presented at the 7e **Colloque national de démographie sur les âges de la vie**, Strasbourg, May 1982.

Life Expectancy and Life Expectancy in Good Health

Examination of the results obtained by Wilkins and Adams yields three points that deserve further attention:

1. life expectancy in good health reached, in 1978, a value almost equal to the mean duration of life in the mortality conditions prevalent in Canada around 1931,

2. differences between males and females are less for duration of life in good health than for total length of life,

3. the ranking of regions by life expectancy in good health is not the same as that for total life expectancy.

These specific points obviously lead to a more general reflection on the relationship between these two indicators.

The first point mentioned shows clearly that the secular increase in mean length of life is not the result of a simple accumulation of additional years of life in poor health. Not only do people live longer today than in the past, they also live longer in good health. But is this to say that they also live less years in poor health?

In spite of appearances, the second point mentioned does not make it possible to give a definite answer to this question. It is not known in fact if, for given mortality conditions, the prevalence of disability was formerly the same for both sexes. Lacking this important piece of evidence, one cannot conclude that women owe their greater number of years lived in poor health to their greater longevity.

Other more convincing evidence is, however, available. The 1951 and 1978 surveys suggest that disability has become more prevalent in Canada over the past 30 years. At least for the recent past, it is therefore highly probable that mean length of life in poor health has also increased.

This latter remark reveals that the last three decades have been marked by diverging trends in mortality and prevalence of disability. This phenomenon is not restricted to Canada alone. In the United States, for example, data collected for the period 1966-1976 indicate the coexistence of a major decrease in mortality and a spectacular increase in disability.[17] In these conditions, the hypothesis of a recent decline in life expectancy in good health cannot be ruled out.

The third point mentioned is consistent with this hypothesis since, at the regional level, it is not the same populations which have enjoyed both better life expectancy in good health and the greater longevity. It is not clear how these regional differences should be interpreted, however, due to the lack of comparable data for the past.

Quality-adjusted Life Expectancy

When calculating life expectancy in good health, only those years lived without disability are measured. No value is therefore attached to the years lived in a disabled state, whatever might be the degree of disability.

A less extreme position is adopted when calculating quality-adjusted life expectancy. Years lived in a state of disability are taken into account, but are attributed a proportionately lower value. If the value 1 is assigned to a year of life in good health, each year of disability would receive a score between 0 and 1, with the score being lower the greater the disability. Multiplying the years lived by their respective values yields "quality-adjusted life expectancy" ("quality" referring to quality of life).

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[17] Colvez, A. and Blanchet, M., "Disability Trends in the United States Population 1966-76: Analysis of Reported Causes", **American Journal of Public Health**, 71,5, May 1981, pp. 464-471.

This is quite similar to the method which consists in giving each member of a population a score which expresses their health status. The indication that is sought here is no longer the level of positive health (good health), but the level of mean intrinsic health of the population. This new indicator will give a picture of the health situation that is closer to that provided by life expectancy than that furnished by life expectancy in good health.

The results obtained by Wilkins and Adams show this clearly. When one takes into account the degree of disability, the gap between males and females widens and takes on a dimension quite similar to that which results from comparing total life expectancies themselves (Table 32). The new ranking of regional populations also shows less divergence from the classification by life expectancy.

Overview

Depending on the value attributed to years lived, three different descriptors may be obtained:

1. life expectancy at birth, which results from attributing a value equal to 1 to each year lived,

2. life expectancy in good health, obtained by assigning a value equal to 1 only to disability-free years lived and a zero value to other years lived,

3. quality-adjusted life expectancy, calculated by assigning a non-zero value to each year lived, this value being 1 for disability-free years and less than 1 for other years.

The last two descriptors are obviously more complex than the first, since they incorporate into the measurement of length of life an appreciation of the quality of life.

As its name indicates, life expectancy in good health provides an indication of the level of positive health of the population. For both analysis and decision-making purposes, values of this indicator should be compared with those of life expectancy itself to measure, in terms of differences or ratios, the degree of negative health. When interpreting the results, it should, however, be remembered that these figures are only averages, and that years of poor health do not all occur at the end of a lifetime.

Quality-adjusted life expectancy provides an indication of the level of mean intrinsic health of the population. It should be stressed that health status is evaluated here according to the degree of disability, and thus without explicitly taking into account other important dimensions such as health practices or the presence of chronic disorders.

III TECHNICAL DISCUSSION

Cautionary Remark

Knowledge of the prevalence of disability in a population is a prerequisite to calculating life expectancy in good health, but bringing together the statistical data necessary to measure this prevalence is not an easy task.

The first difficulty is one of terminology. Concepts such as impairment, disability and handicap are close enough to be easily confused or defined differently by different researchers. As mentioned in Chapter 5, the World Health Organization has recently adopted official definitions,[18] but it is too early to tell what will result from this standardization attempt.

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[18] W.H.O., **International Classification of Impairments, Disabilities and Handicaps.** A manual of classification relating to the consequences of disease, Geneva, W.H.O., 1980, 207 p.

The second problem, which is related to the first, is the diversity of criteria retained for defining cases of disability. The most commonly used criteria are:

- confinement to bed or home,
- restriction of principal activity (school, work, housekeeping),
- being dependent on others in performing the basic acts of everyday life (washing, dressing, feeding, etc.).

The number of cases observed obviously depends on the criterion, or combination of criteria that are adopted.

The third difficulty is in the inadequacy and the paucity of available statistics. Current health statistics enable a study of only those disabilities which necessitate a stay in hospital or in a specialized institution. Many other cases of disability can only be observed by surveying the population, but such surveys are infrequently taken, or are limited to certain groups of persons. It is thus only on rare occasions that the minimum amount of essential data are successfully gathered, rather than just a few scattered pieces of the disability puzzle.

These problems, and they are not the only ones, must be overcome before the calculation of life expectancy in good health can be done on a routine basis. This is to say that the data available to date are scarce and can rarely be compared to data for other periods or areas.

Recent Statistics on Disability in Canada

The 1978 survey of the health of Canadians (**op. cit.**) gathered considerable information on the prevalence of disability in the non-institutionalized population. This information may be divided into three sections, which are briefly described below.

1. **Disability Days**

To obtain the most exact information possible, respondents were asked only about their disability days during the two weeks preceding the interview. These disability days included days spent in bed, days during which the respondents had to abandon their principal activity, or days when activities were restricted for health reasons. After adjustment for double-counting, the total number of disability days during the two-week period were determined. The annual number of disability days for the entire sample were then calculated by multiplying this total by 26.

The fact that observation was limited to the two weeks preceding the survey does not mean that the disability might not have been of longer duration. It is accordingly unfortunate that the term "short-term disability" has become commonly used in this connection. A more appropriate expression should be found in order to avoid any misunderstanding about the interpretation of the statistics obtained.

2. **Restriction of Normal Activities**

The degree of disability of respondents at the time of the survey was determined according to the impact of their present state of health on their principal activity (school attendance, work, housekeeping) or, failing this, on other normal activities (sports and leisure activities, social activities, shopping trips, etc.). Depending on their replies, these persons were placed in one of the following four groups:

- persons unable to perform their normal main activity,
- persons restricted in performing their main activity,
- persons performing their main activity normally but obliged to restrict their other activities,
- persons not suffering from any restriction of their normal activities.

The tables thus obtained show the prevalence of disability at the time of the survey (point prevalence), while statistics on disability days indicate the annual volume of disability (annual prevalence).

The restrictions recorded with regard to activities may go back to the individual's birth, or only a few years, months or weeks. Their duration is thus highly variable. It was found to be in the order of 11 months on the average, but it increased with age. The expression "long-term disability", commonly used to characterize the information collected in this manner, should obviously be used with a certain amount of caution.

3. Disabilities Resulting from Certain Impairments

The survey also enabled information to be gathered on disabilities resulting from dental, visual or hearing problems.

It is clear that statistics on these three types of disability may not be summed, since one person may suffer from disability in two or three of these areas.

It should also be noted that almost all of these statistics are drawn up from statements made by respondents about any restriction to their normal activities. These restrictions, however, are partially dependent on many factors exogenous to health status: nature and difficulty of the activity, professional status of the person, attitudes towards sickness, work, etc. These factors certainly hinder the comparison of results obtained for widely differing sub-populations.

In addition, these recent statistics deal only with persons living outside of institutions. To determine the prevalence of disability in the entire population, it would be necessary to add to these statistics data collected on institutionalized persons. This is not an easy task. Since these data are not systematically collected, one must be content with assembling from different types of administrative statistics the information which exists on long-term stays in hospitals, rest homes and other specialized institutions.

Calculating Disability-free Life Expectancy

Disability-free life expectancy is calculated by subjecting a synthetic cohort to all the risks of disability and death observed at various ages during a given period. This is done in the following way:

(a) a life table is first computed to obtain the number of years lived at each age by members of the synthetic cohort (see I-03),

(b) years lived A_x are then multiplied, at each age x, by the complement of the fraction of year f_x lived in a disabled state by persons of that age,[19]

(c) all these quantities $[A_x\ (1-f_x)]$ are then added together to obtain the total number of disability-free years lived by members of the synthetic cohort.

Disability-free life expectancy is the result of dividing the total number of disability-free years lived by the initial size of the synthetic cohort, i.e. by its size at birth (S_0).

The fraction of a year f_x may be calculated in two different ways depending on the nature of available statistics: number of disability days or number of persons suffering from disability. The first method consists in simply dividing by 365 the mean annual number of disability days per person of age x. The second consists in estimating fraction f_x as the average prevalence of disability during the year for persons of age x. This second method is theoretically equivalent to the first, as may be shown by the following reasoning:

(a) the annual number of disability days is obviously equal to the sum of the 365 daily totals of persons disabled, and

19 Sullivan, D.F., "A Single Index of Mortality and Morbidity", **Health Reports**, 86,4, 1971, pp. 347-354.

(b) the result of dividing the arithmetic mean of these 365 daily totals by the size of the appropriate population may thus be interpreted either as the average prevalence of disability during the year or as the fraction of a year lived in a disabled state per person.

In practice, the average prevalence of disability during a year may be determined without knowing the day-to-day numbers of disabled persons. To arrive at a very close estimate, one only has to know this figure at times appropriately spaced to take into account seasonal variations in health status. In surveys, this average prevalence is calculated as the average of the point prevalence observed at various times throughout the year, in different but equally representative samples of the population.

It should be noted here that since there are normally two separate sources of information, more lengthy calculations are often necessary. Using data available on the institutionalized population, or on long-term stays in hospitals or other institutions, the fraction of a year lived in institutions is calculated. This fraction enables the total years lived to be divided into years lived in an institution and years lived out of an institution. The fractions derived from survey data on the non-institutionalized population are then applied to the years lived outside institutions. Table 33 shows how this is done.

TABLE 33. Calculation of Disability-free Life Expectancy, Males, Canada, 1978

Age interval	Years lived (taken from the life table)	Rates of institutionalization[1]	Years lived: Institutionalized	Years lived: Not institutionalized	Rates of disability[1]	Years lived: In a disabled state	Years lived: Disability-free
	(1)	(2)	(3)=(1)x(2)	(4)=(1)-(3)	(5)	(6)=(4)x(5)	(7)=(4)-(6)
0-15 years	1,475,419	0.0020	3,008	1,472,411	0.054	79,986	1,392,425
15-25 "	972,823	0.0029	2,838	969,985	0.066	63,644	906,341
25-45 "	1,896,306	0.0027	5,195	1,891,111	0.089	168,395	1,722,716
45-65 "	1,699,064	0.0059	10,050	1,689,014	0.128	385,717	1,303,297
65 years and over	1,037,206	0.0527	54,611	982,595	0.390	383,530	599,065
Total	**7,080,818**		**75,702**	**7,005,116**		**1,081,272**	**5,923,844**
Life expectancies	70.81		0.76	70.05		10.81	59.24

[1] These calculations were made prior to rounding the above rates.
Source: Table 1, in Wilkins, R. and Adams, O.B., **op. cit.**, p. 1074.

Calculating Quality-adjusted Life Expectancy

Since disability is a matter of degree, the calculations described above may be made with a view to classifying years lived in a disabled state according to the degree of disability. To do this, all that is needed is the information necessary for calculating the fractions of a year lived in the various states of disability that are to be distinguished. The final result is the disaggregation of life expectancy at birth into a number of partial and additive life expectancies: disability-free life expectancy and life expectancy in various states of disability.

By attributing a value h_j to each health status, and designating as e_j life expectancy in that state of health, a synthetic index E can be calculated using the formula:

$$E = \sum_{j=1}^{n} e_j h_j$$

This synthetic index is equal to life expectancy at birth if one assumes that $h_j = 1$ regardless of the value of j and it is equal to disability-free life expectancy if one considers that all disabled states have a zero value and that absence of disability has a value equal to 1. It takes an intermediate value between these two life expectancies when the values of h_j are distributed over a scale between 0 and 1 for various states of disability. In this case, the term "quality-adjusted life expectancy" can be used, "quality" referring to quality of life.

Applying this definition is not an easy task. On the one hand, the statistics normally available do not allow disabled states to be properly classified due to a paucity of information on certain important dimensions of disability such as confinement to bed or an armchair and the dependency on others in performing the basic activities of everyday life. On the other hand, the value attributed to each disabled state is somewhat arbitrary, since the only basis for choosing such a value is the opinion of a majority of experts and patients. In spite of these difficulties, it is worthwhile to attempt to calculate "quality-adjusted life expectancy", if only to give more depth to conclusions drawn from the analysis of disability-free life expectancy.

Table 34, borrowed from Wilkins and Adams (**op. cit.**), gives an example of this calculation using Canadian data.

TABLE 34. Calculation of Quality-adjusted Life Expectancy, Males, Canada, 1978

Health status	Life expectancy	Weighting factor	Years lived, adjusted for quality
	(1)	(2)	(3) = (1) x (2)
	years		years
Institutionalized disability	0.8	0.4	0.3
Cannot do major activity	3.0	0.5	1.5
Restricted in major activity	5.4	0.6	3.2
Minor activity restriction	1.3	0.7	0.9
Only short-term disability	1.1	0.5	0.6
Not restricted in activities (no disability)	59.2	1.0	59.2
Total	**70.8**		**65.8**

Source: Taken from Wilkins, R. and Adams, O.B., **Healthfulness of Life**, Montreal, Institute for Research on Public Policy, 1983, Table 4.4 p. 73, and pp. 75-78.

CHAPTER 7

INDICATORS OF HEALTH PROBLEMS

After having determined the health level already reached by the population, the next step is obviously to look at the obstacles to moving to higher health levels. A detailed picture of the health situation is then drawn up in an attempt to answer the following questions:

1. is the population highly exposed to risk factors that jeopardize its present and future health?

2. what accidents and diseases are the most common or have recently increased in frequency?

3. what are the main causes of death or disability?

4. what potentials are lost to the population as a result of the existence of these various health problems?

This chapter will deal with the main indicators which may be used to find answers to these questions.

Some of these indicators are drawn from demography, others from descriptive epidemiology. In conformity with common practice in these two disciplines, both types are used here in order to cover the entire range of disease-related phenomena. The treatment of epidemiological indicators will be somewhat briefer, but an attempt will be made to show how these are related to demographic indicators in order to better illustrate the interest and limits of the latter type.

I-05: PREVALENCE OF A RISK FACTOR

I DESCRIPTION

Definition

Proportion of persons exposed to a controllable factor involved in the emergence or worsening of one or more health problems.

Descriptive Function

The prevalence of a risk factor is an indispensable element for calculating the fraction of morbidity (or mortality) that may be attributed to this factor (see I-13) and to analyse the health situation of the population.

Indication Sought

To the extent that exposure to the factor may truly be controlled, its prevalence is an estimate of the fraction of the population whose future health could be improved by the appropriate preventive measures or encouragements to change the problematic behaviour.

II INTERPRETATION

The emergence and development of health problems depend on many factors related to human biology, the physical and social environment, the lifestyles of individuals and the delivery of health care.[1] In the public health field, priority is given to factors that are controllable and responsible for a substantial portion of morbidity and premature mortality. Among the factors which have been studied over the past twenty years, the following will give an idea of their diversity: high cholesterol levels, high blood pressure, industrial and urban pollution, alcoholism, smoking, obesity, sedentary lifestyles and refusal to wear seatbelts.

Persons exposed to such factors experience major health problems earlier than others and die younger, so it is important to know their numbers and the proportion they constitute of the total population. Table 35 gives as an example the prevalence of three risk factors in the adult or elderly population. For two of these factors, persons previously exposed must also be taken into account, since the additional risks caused by the factor recede only slowly after exposure ends.

A more complete description would also include the distribution of exposed persons by intensity and duration of exposure. In the case of cigarette smoking, for instance, smokers would be broken down by their daily consumption (intensity) and the length of time they have been smoking (duration). Since the risks become greater with longer durations and increased exposure, this double-entry table would make it possible to calculate an indicator that is not discussed here: the proportion of individuals who are at high risk.

Whatever the indicator used, it is of little interest to the layman as long as the consequences of exposure for morbidity and mortality have not been calculated. To make the figures in Table 35 more meaningful, the number or proportion of deaths would have to be added, as well as cases of illness and disability days attributable to each risk factor. This will be done when calculating "attributable fractions" (see Indicator I-13).

The effects of the current prevalence of a risk factor are not, however, limited to the present, they will last for several decades to come. Due to the long period separating the onset of exposure from the appearance of the many health problems which derive from it, present prevalence predicts the future extent of these problems. Thus, looking at the increase in cigarette smoking and alcohol

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[1] Lalonde, M., **A New Perspective on the Health of Canadians**, Health and Welfare Canada, Ottawa, 1974, 76 p.

consumption from one generation to the next (Table 35), one can ascertain that more of the young women of today will die of lung cancer, cancer of the esophagus or cirrhosis of the liver than in the past. The prevalence of risk factors is thus an extremely useful indicator, since it allows the advance discovery of certain obstacles to an improvement in the health of the population while suggesting ways of dealing with these problems.

TABLE 35. Prevalence of Three Risk Factors, Canada, 1978-79

Age group	Hyper-cholesteremia[1]	Type of drinker		Type of cigarette smoker	
		Current	Former	Current	Former
		percentage			
Males:					
15-19 years	–	60.7	1.3[2]	32.3	14.0
20-24 "	4.4	87.2	2.1	48.9	17.0
25-34 "	10.3	81.3	3.5	44.6	26.2
35-44 "	12.6				
45-64 "	23.3	76.5	6.2	42.2	34.6
65 years and over	15.0	53.9	10.0	29.5	41.2
Females:					
15-19 years	0.7	52.1	3.1[2]	33.9	16.6
20-24 "	5.5	71.1	2.6	45.2	19.8
25-34 "	2.5	63.9	2.8	37.2	21.4
35-44 "	2.1				
45-64 "	24.3	51.5	3.2	32.0	17.3
65 years and over	33.8	29.3	4.0[2]	13.7	11.2

1 i.e. cholesterol levels greater than 250 mg/dL.
2 The margin of error is between 20% and 39%.
Source: Canada. Health and Welfare Canada and Statistics Canada, **The Health of Canadians: Report of the Canada Health Survey**, Supply and Services Canada, Ottawa,1981, pp. 28, 50 and 154.

III TECHNICAL DISCUSSION

Statistics on retail sales of certain products provide interesting information on the exposure of the population to various risk factors. These provide invaluable chronological series on average consumption per person of products such as alcohol[2] and tobacco.[3]

The prevalence of risk factors, however, can only be obtained by surveying the population. Examples that can be mentioned are the Smoking Behaviour Survey in Canada,[4] the 1970-72 study on nutrition in Canada[5] and the Canada Health Survey in 1978-79 **(op. cit.)**.

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2 Brown, M. and Wallace, P., **International Survey, Alcoholic Beverage Taxation and Control Policies** (4th Ed.), Brewers Association of Canada, Ottawa, 1980.
3 Todd, G.F., **An Estimate of Manufactured Cigarette Consumption in Canada by Sex, Age and Cohort 1921-1975** (Publication No. 1, WHO Collaborating Centre for Reference on the Assessment of Smoking Habits), Waterloo, Faculty of Mathematics, University of Waterloo, 1979, 15 p.
4 Millar, W.J., **Smoking Behaviour of Canadians, 1981**, Health and Welfare Canada, Ottawa, 1983.
5 Nutrition Canada, **Nutrition, a national priority**, Report to the Department of National Health and Welfare, Information Canada, Ottawa, 1973.

I-06: INCIDENCE RATE OF A DISEASE

I DESCRIPTION

Definition

By "incidence rate of a disease" is usually meant the average number of new cases for that disease per year per 10,000 or per 100,000 population.

Descriptive Function

The annual frequency of new cases is currently used by epidemiologists to follow the spread of a disease over time and space, or in specific sub-populations. In contrast to some other measurements of morbidity, this frequency does not depend on the duration, seriousness or recurrence of the disease.

Indication Sought

Vulnerability of the population to the disease in question.

II INTERPRETATION

The concept of incidence was originally created to better follow the spread of communicable diseases in populations. It was later realized that this indicator is also very useful in studying the appearance of chronic illnesses. With time, its use thus became more widespread.

Data taken from Canadian cancer registries will be used to illustrate what use may be made of the incidence rates.

Annual Frequency of New Cases in a Population

Table 36 shows the incidence rates of various cancers in Saskatchewan for the years 1961-65 and 1971-75. These are standardized rates obtained by applying to the Canadian population at the 1971 census the Saskatchewan rates by age and sex. Variations in these rates over time are thus exempt from interference due to changes in the age composition of the population.

These figures are shown here mainly to emphasize the fact that the incidence of non-communicable diseases may vary rapidly over time, either upwards or downwards. When these variations cannot be explained by a change in diagnostic practices or by errors in counting new cases, they reveal a major change in the vulnerability of the population to various diseases. The rapidity of the change would suggest that it could not be attributed to a transformation in the biological characteristics of the population, but rather to a difference in exposure of the population to the exogenous factors of the disease.

If the risk factors of the disease have already been identified, one would naturally seek to confirm the above hypothesis by comparing trends in incidence rates to those of indicators of exposure of the population to the risk factors (I-05). A further step would be to estimate the fraction of morbidity attributable to each risk factor (I-13).

Frequency of New Cases in a Cohort

By combining age-specific incidence rates with data from the general life table, it is possible to estimate the average probability of developing the disease during a lifetime. The proportion is simply calculated of persons who would develop the disease in a cohort subjected until extinction to the morbidity and mortality conditions prevalent in the observed population.

TABLE 36. Probability (per 100) of Developing Cancer by Major Site, Standardized Incidence and Mortality Rates per 100,000, Saskatchewan, 1961-65 and 1971-75

Site and ICDA code (8th revision)	Sex	Probability of developing cancer		Incidence rate		Mortality rate	
		1961-65	1971-75	1961-65	1971-75	1961-65	1971-75
		per 100		per 100,000			
Breast (174)	Males	–	–	0.3	0.5	0.1	0.2
	Females	7.5	8.0	61.2	64.3	19.4	20.7
Prostate (185)	Males	4.9	6.0	40.6	50.2	14.8	18.0
	Females	–	–	–	–	–	–
Trachea, bronchus, lung (162)	Males	2.8	4.2	26.3	38.1	23.7	35.7
	Females	0.7	1.1	5.1	9.1	4.1	6.9
Large intestine except rectum (153)	Males	1.7	2.3	15.1	20.9	9.0	11.9
	Females	2.6	3.1	18.0	19.7	11.2	12.0
Stomach (151)	Males	2.1	1.6	18.9	13.7	19.6	12.3
	Females	1.4	1.1	8.6	6.9	8.9	6.3
Corpus uteri (182)	Males	–	–	–	–	–	–
	Females	2.0	2.5	17.3	20.2	1.2	1.2
Cervix uteri (180)	Males	–	–	–	–	–	–
	Females	1.4	1.0	13.2	9.7	3.9	3.4

Source: Canada. Health and Welfare Canada, **Cancer Incidence Trends, Saskatchewan, 1950-1975,** Ottawa, 1979, pp. 9 and 11.

According to the Saskatchewan data for 1971-75, 27.6% of males and 28.2% of females would develop cancer at some time in their lives. It can easily be seen that these proportions are much more eloquent than the rates normally used to measure the extent of morbidity due to cancer.

This highly suggestive indicator is, however, not linked specifically to the incidence of disease, it also varies with average length of life. Particularly when incidence increases with age while remaining constant over time, values of the indicator will rise with an increase in mean length of life. The next indicator described does not have this disadvantage.

Cumulative Incidence of a Disease up to a Given Age

The cumulative incidence up to a given age may be obtained by cumulating the incidence rates for previous ages, or by taking a function of this cumulation. This is in fact the proportion of persons who would develop the disease before the age in question if death from other causes did not prematurely remove some of them from exposure to this disease.

Comparison of this indicator with the previous one enables its specificity to be emphasized. According to Table 37, the cumulative incidence of cancer up to age 75 for Saskatchewan was 27.2% for males and 22.4% for females, while the frequency of new cases before that age was only 18 to 19% for each sex. Differences between the values of these two indicators are due to the fact that the effect of mortality from other causes on the duration of exposure to the risk of cancer is eliminated from calculation of the first and not from that of the second.

The cumulative incidence before an advanced age is simple to calculate and allows comparisons to be made over time and space without the use of an arbitrary standard population. It is used in Table 37 to compare cancer incidence in various Canadian regions or provinces. The values obtained vary sufficiently to underline the differential vulnerability of provincial populations to various forms of cancer and to cancer in general.

TABLE 37. Cumulative Incidence of Cancer up to Age 75, Canada, 1969-72

Province or region	Males				Females			
	Bronchus	Prostate	Large bowel	All sites	Breast	Large bowel	Cervix uteri	All sites
	per cent							
Alberta	4.7	3.7	3.2	24.6	6.2	2.9	1.3	20.9
British Columbia	6.8	4.4	4.7	31.2	8.8	4.1	1.8	28.6
Manitoba	5.6	4.0	3.9	28.8	7.0	3.3	1.7	24.8
Maritime provinces	4.9	3.3	3.9	24.9	6.5	4.0	2.2	22.9
Quebec	5.5	3.1	3.3	24.0	6.2	3.1	1.6	20.5
Saskatchewan	4.6	4.4	3.7	27.2	6.9	3.3	1.0	22.4
Newfoundland	4.4	2.4	4.4	28.3	4.9	3.6	2.1	20.6

Source: Waterhouse, J., Muir, C., Correa, P., Powell, J., **Cancer Incidence in Five Continents**, Vol. III, (I.A.R.C. Scientific Publications No. 15), Lyon, International Agency for Research on Cancer, 1976. pp. 447 and 450.

Incidence, Lethality and Mortality

Although the incidence of many diseases, such as cancer[6] or acute myocardial infarction[7] is known to vary greatly from time to time or from place to place, statistical observation of the morbidity of populations is still far from perfect. The fact that there are only very few and only very specific permanent disease registers and epidemiological surveys means that, for a given population, one can at best know the incidence of only a few diseases. It is thus necessary to determine to what extent mortality statistics can provide alternate substitute indicators.

Let us first recall that a disease is selected as the cause of death when it is at the origin of the morbidity process which has led to death. Diseases that only rarely trigger such processes, or which intervene mainly in the form of complications in a process that has already begun, are thus underrepresented in current statistics on causes of death.

Therefore, in a great number of cases the mortality attributed to diseases does correspond, with a certain time lag, to the incidence of the diseases weighted by a severity factor which is the proportion of new cases which terminate with death because of the disease. Table 36 gives a good

6 Muir, C.S. and Péron, Y., "The Etiology of Cancer: Special Demographic Situations", **Seminars in Oncology**, 3, 1, March 1976, pp. 35-47.
7 W.H.O., "Myocardial Infarction Community Registers", **Public Health in Europe**, 5, 1976, 232 p.

illustration of this: the ratios between mortality rates and incidence rates in 1971-75 rank on a scale that conforms quite well to the extent to which the various cancers are lethal. When this is the case, and when in addition lethality varies little over time, temporal or spatial variations in mortality reflect variations in incidence.

III TECHNICAL DISCUSSION

Detecting and Recording New Cases of Disease

On the whole, the detection of new cases of disease by the health care system is very incomplete. A new case has more chances of being detected the more regularly a person consults the doctor, the more lasting and severe the manifestations of the disease, and the better defined and more easily identifiable the disease. It is thus only in the case of the most serious diseases that detection is nearly total.

This detection generally occurs during the exteriorization phase of the disease, and thus for chronic diseases this is quite late in the process. Campaigns among high-risk groups have led to earlier detection. By convention, it is the date of the first diagnosis that is necessarily taken as the date on which the disease appeared.

Counting new cases detected by the health care system calls for the centralization of diagnoses, death certificates and autopsy reports, with a view to forming permanent disease registries. Such registries exist in Canada for a limited number of diseases.

The oldest of these registries deal with notifiable communicable diseases. Information collected in each province is collated by Statistics Canada and published at the national level.[8]

Among the more recent registries[9] are: the National Cancer Incidence Reporting System (nine provincial registries), the Canadian Renal Failure Register (60 dialysis and transplant centres), the Canadian Congenital Anomalies Surveillance System (six provinces) and the British Columbia Health Surveillance Registry. A cardiovascular diseases registry will soon be set up in Alberta.

Normal Method of Calculating Disease Incidence Rates

The crude incidence rate of a given disease is obtained by multiplying by 100,000 the ratio of the number N of new cases recorded during the year to the size P of the population at mid-year, i.e.:

$$I = (N/P) \times 100{,}000$$

As a general rule, and if necessary, recurrences are excluded from the number of new cases, so that the numerator of the rate shows only the number of first occurrences of the disease.

In the same way, the incidence rate at age x is calculated by multiplying by 100,000 the ratio of the number N_x of new cases observed at age x to the size P_x of age category x at mid-year:

$$I_x = (N_x/P_x) \times 100{,}000$$

This calculation is ordinarily made by age group rather than by single years of age, and for each sex separately.

In an attempt to limit insofar as is possible the random fluctuations common to small numbers, new cases recorded are often combined for several consecutive years. The above formulae may still be used in such cases, provided the corresponding values of P or P_x are also computed. The rates thus obtained still have an annual dimension, since they give the mean annual number of new cases per 100,000 persons of all ages or of age x.

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8 Statistics Canada, **Annual Report of Notifiable Diseases**, Catalogue 82-201.

9 For more details, see: Canada. Health and Welfare Canada, "Disease Registries", **Chronic Diseases in Canada**, 2, 4, March 1982, pp. 41-50.

For purposes of comparison between periods or areas, standardized incidence rates are also calculated. The method of calculation is that used to obtain standardized death rates, with age-specific death rates being replaced by the age-specific incidence rates (see the technical discussion of Indicator I-02).

Probability of Developing a Disease

As mentioned on several occasions, the size P_x of age group x represents the number of years lived at age x by members of the population. Consequently, the incidence rate at age x, that is, I_x, gives the number of new cases per 100,000 years lived at age x.

Based on this last interpretation of the incidence rate, the probability of catching a disease can be calculated as follows:[10]

1. from the general life table, take the years lived at various ages by members of a synthetic cohort subject to the mortality conditions prevailing in the population under observation,

2. calculate the number of new cases incurred at each age in such a cohort by multiplying years lived A_x (or L_x) by incidence rates I_x,

3. divide the sum of all the new cases thus calculated by the size at birth of the synthetic cohort.

It may be seen that the final result is the proportion of persons catching the disease in a synthetic cohort subject to the morbidity and mortality conditions prevailing in the observed population.

The corresponding indicator in the area of mortality is the probability of eventually dying from a specified cause (Indicator I-10).

Cumulative Incidence of a Disease up to Age a

Following the example of the authors of the third volume of "Cancer Incidence in Five Continents" **(op. cit.)**, this risk can be calculated as being the sum of the incidence rates at preceding ages, provided the following three conditions are observed:

1. the rates must be calculated by single year of age,

2. the scaling factor (e.g., 1,000, 10,000) by which the ratio of new cases to the total size of the population is multiplied must not be taken into account,

3. the sum obtained must be less than 0.1.

If the rates have been calculated by age group, each rate must first be multiplied by the duration of the corresponding age interval expressed in years. If the sum of these products or of the rates is greater than 0.1, the risk would be calculated as the complement of the natural antilogarithm of the opposite of this sum, i.e. by 1-exp (-sum of rates). This more complicated calculation is rarely necessary for given diseases considered separately.

The corresponding indicator in the area of mortality is the cumulative risk of dying from a specified cause (Indicator I-11).

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10 Zdeb, M.S., "The Probability of Developing Cancer", **American Journal of Epidemiology**, 106, 1977, pp. 6-16.

I-07: PREVALENCE RATE OF A DISEASE

I DESCRIPTION

Definition

Proportion of persons suffering from the disease at a given point in time (point prevalence) or having suffered from it during a given period (period prevalence).

Descriptive Function

Prevalence, which is a measurement of the frequency of morbid states in the population, enables one to grasp the extent of health problems brought on by the development of a disease. This prevalence depends on the frequency of new cases and recurrences as well as on the mean duration of the disease.

Indication Sought

Proportion of the population requiring specific treatment and preventive care.

II INTERPRETATION

While simple to define, prevalence of disease is often difficult to measure, and its level thus varies considerably depending on the nature of data used. This will be illustrated here in order to emphasize the lack of comparability of statistics coming from different sources.

Point Prevalence of Perceived Morbidity

During the 1978-79 survey on the health of non-institutionalized Canadians, a list was drawn up of the various health problems affecting persons age five and over at the time of the home interviews. The symptoms, complaints or diseases mentioned by respondents were then coded using the International Classification of Diseases in order to draw a picture of morbidity as perceived by respondents.

Table 38 gives estimates of the prevalence of morbidity as perceived by the non-institutionalized Canadian population. It may be noted that:

1. more than half of this population suffers from health problems,

2. the proportion of persons in poor health increases with age, as do the number of health problems reported,

3. women have more health problems than men in adulthood and old age.

A few explanatory remarks are necessary in order that these results not give rise to undue concern.

These results certainly do not mean that only 46% of Canadians feel they are in good health. In comparable surveys carried out in the United States, almost 90% of respondents felt they were in good or excellent health, even though a fair number of them were experiencing some health problem at the time.[11] In other words, the prevalence of a feeling of good health was much higher than the complement of the prevalence of perceived morbidity.

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[11] United States. Department of Health, Education and Welfare. National Center for Health Statistics. **Health, United States, 1975**, Washington, D.C., Government Printing Office, 1976, vi + 612 p.

TABLE 38. **Proportion of Persons Having at Least One Health Problem and Average Number of Problems Per Person in Poor Health, Canada, 1978-79**

	Less than 15 years			15-64 years			65 years and over			Total		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Total population (E)[1]	5,531	2,833	2,699	15,473	7,697	7,775	2,019	887	1,132	23,023	11,417	11,606
Number of individuals having at least one health problem (M)[1]	1,928	1,005	924	8,853	3,968	4,885	1,729	742	987	12,510	5,714	6,796
Total number of health problems (P)[1]	2,634	1,385	1,249	17,692	7,177	10,515	5,200	1,997	3,203	25,526	10,559	14,967
Proportion of persons having at least one problem: M/E (percentage)	34.9	35.5	34.2	57.2	51.6	62.8	85.6	83.7	87.2	54.3	50.0	58.6
Average number of problems per person in poor health: P/M	1.37	1.38	1.35	2.00	1.81	2.15	3.01	2.69	3.25	2.04	1.85	2.20

[1] In thousands.

Source: Canada. Health and Welfare Canada and Statistics Canada, **The Health of Canadians: Report of the Canada Health Survey**, Supply and Services Canada, Ottawa, 1981, p. 115.

This apparent paradox is obviously due to the tremendous variation in the nature, duration and severity of the various health problems reported by individuals. The majority of these problems are perceived as minor or of passing nature: according to the Canada Health Survey, over half of them involved at the time no disability, medical examination or medication. If these problems are all treated as equally important, the resulting deterioration in health would certainly be overestimated and thus it is preferable to calculate this deterioration by the prevalence of disability (see I-04 and I-12).

Prevailing Morbidity as Perceived by the Health Care System

Table 39, also taken from the 1978-79 survey, shows the frequency with which respondents consulted a health care professional in the two weeks preceding the interview, for the 12 most commonly mentioned problems. This table illustrates the relation that exists between morbidity perceived in the short-term by the health system and morbidity prevailing at the same moment in the population living at home.

These two types of morbidity differ both in volume and in structure. Only 13% of problems resulted in a consultation with a health professional in the preceding two weeks. While the most frequently mentioned problems were arthritis and rheumatism, limb and joint disorders, hay fever and other allergies, the principal reasons for consultation were dental problems, pain in limbs and joints and other health problems not included among the 12 most commonly reported.

The main merit of this comparison is that it points out the necessity of taking into account the frequency of consultation in interpreting morbidity statistics based on the activity of health professionals and thus of making a clear distinction between perceived morbidity and diagnosed morbidity (see Chapter 5).

Perceived Morbidity and Objective Morbidity

To estimate the prevalence of a disease in a population, the surest method is to have a representative sample of this population undergo a systematic examination aimed at detecting the disease. If the examination is valid, "objective" morbidity has been determined, as opposed to "subjective" or perceived morbidity, which is measured through statements made by individuals.

The 1978-79 survey permitted the comparison of these two types of morbidity for hypertension (Table 40). Objective morbidity is higher than perceived morbidity for males (9% against 6%) and lower for females (7% against 9%). In addition, two-thirds of those with high blood pressure were unaware of this condition, while close to a third of those who declared they had high blood pressure had normal blood pressure at the time of measurement.

The differences observed between these two measures of morbidity would appear to be principally due to the following reasons:

1. persons who were unaware of their condition were still in the asymptomatic phase of the disease,

2. most of those who complained of high blood pressure were taking medication meant to lower the pressure.

The same situation would also be observed for other chronic ailments, which are characterized by a long occult phase and periods of remission.

As this example shows, although perceived morbidity allows health needs to be estimated independently of the frequency of consultation, it nevertheless generally provides only a poor estimate of these needs. Attempts to measure objective morbidity thus become extremely useful.

TABLE 39. Frequency of Consultation of Health Professionals in the Two Weeks Preceding Interview, by Type of Health Problem, Canada, 1978-79

Type of health problem		Health problems			Consultations[1]		
		Total	Males	Females	Total	Males	Females
Arthritis and rheumatism	No.	2,440,000	844,000	1,596,000	66,000	22,000[2]	44,000
	%				2.7	2.6[2]	2.8
Limb and joint disorders	No.	2,334,000	1,182,000	1,153,000	295,000	139,000	156,000
	%				12.6	11.8	13.5
Hay fever and other allergies	No.	2,157,000	987,000	1,170,000	121,000	67,000[2]	54,00
	%				5.6	6.8[2]	4.6
Skin disorders	No.	2,064,000	756,000	1,308,000	145,000	45,000	100,000
	%				7.0	6.0	7.6
Dental problems	No.	1,697,000	739,000	958,000	356,000	143,000	213,000
	%				21.0	19.4	22.2
Hypertension	No.	1,551,000	588,000	963,000	–	–	90,000
	%				–	–	9.3
Sight disorders	No.	1,200,000	449,000	750,000	90,000	42,000[2]	48,000
	%				7.5	9.4[2]	6.4
Headache	No.	1,102,000	292,000	809,000	46,000	15,000[2]	31,000
	%				4.2	5.1[2]	3.8
Hearing disorders	No.	1,028,000	607,000	422,000	104,000	48,000	56,000
	%				10.1	7.9	13.3
Mental disorders	No.	1,000,000	363,000	637,000	115,000	43,000[2]	72,000
	%				11.5	11.8[2]	11.3
Heart disease	No.	847,000	429,000	418,000	94,000	52,000	42,000
	%				11.1	12.1	10.0
Acute respiratory disorders	No.	781,000	355,000	426,000	274,000	106,000	168,000
	%				35.1	29.9	39.4
TOTAL	No.	**25,526,000**	**10,559,000**	**14,967,000**	**3,354,000**	**1,390,000**	**1,964,000**
	%				**13.1**	**13.2**	**13.1**

1 For each sex, percentages are equal to 100 times the number of consultations divided by the number of health problems.
2 The margin of error is between 20% and 39%.

Source: Canada. Health and Welfare Canada and Statistics Canada, **The Health of Canadians: Report of the Canada Health Survey**, Supply and Services Canada, Ottawa, 1981, p. 118.

TABLE 40. Population Five Years and Over, by Reported Blood Pressure, Measured Blood Pressure and Sex, Canada, 1978-79

Measured blood pressure		Total	High blood pressure reported	High blood pressure not reported
Total	No.	**21,302,000**	**1,583,000**	**19,719,000**
	%	**100.0**	**7.4**	**92.6**
Males	No.	**10,536,000**	**607,000**	**9,929,000**
	%	**100.0**	**5.8**	**94.2**
Females	No.	**10,767,000**	**976,000**	**9,792,000**
	%	**100.0**	**9.1**	**90.9**
Normal				
Total	No.	16,560,000	467,000	16,093,000
	%	100.0	2.8	97.2
Males	No.	7,839,000	137,000[1]	7,702,000
	%	100.0	1.8[1]	98.3
Females	No.	8,721,000	330,000	8,391,000
	%	100.0	3.8	96.2
Border-line				
Total	No.	2,859,000	491,000	2,368,000
	%	100.0	17.2	82.8
Males	No.	1,663,000	234,000	1,429,000
	%	100.0	14.1	85.9
Females	No.	1,196,000	257,000	940,000
	%	100.0	21.5	78.5
Elevated				
Total	No.	1,746,000	612,000	1,134,000
	%	100.0	35.1	64.9
Males	No.	963,000	236,000	727,000
	%	100.0	24.5	75.5
Females	No.	784,000	377,000	407,000
	%	100.0	48.1	51.9
Unknown				
Total	No.	137,000[1]	–	124,000[1]
	%	100.0	–	90.5[1]
Males	No.	71,000[1]	–	70,000[1]
	%	100.0	–	98.6[1]
Females	No.	–	–	–
	%	–	–	–

[1] Margin of error between 20% and 39%.

Source: Canada. Health and Welfare Canada and Statistics Canada, **The Health of Canadians: Report of the Canada Health Survey**, Supply and Services, Ottawa, 1981, p. 147.

III TECHNICAL DISCUSSION

Incidence and Prevalence

It is easy to understand that the more new cases there are, and the longer the disease lasts, the higher will be the number of people suffering from the disease. In other words, the prevalence of a disease is a function of the product of its incidence and its mean duration. Two important consequences of this should be kept in mind:

1. diseases rank differently depending upon whether one considers their incidence or their prevalence,

2. incidence and prevalence may vary differently over time if the mean duration of the disease also varies.

Prevalence and Mortality

Any reduction in the lethality of an incurable disease results in a lengthening of its mean duration and a consequent increase in prevalence. For such diseases, prevalence and mortality trends may therefore be divergent.

I-08: HOSPITAL MORBIDITY RATE

I DESCRIPTION

Definition

The number of hospital separations recorded in the year, or the number of days these patients spent in hospital, by medical reason for hospitalization, expressed as a ratio to the total population at mid-year.

Descriptive Function

These rates reflect the frequency with which hospital care is sought, the duration of this care and the reasons for seeking it, with the exception of care provided to outpatients.

Indication Sought

These rates are often used to rank various health problems on the basis of their impact on the average health of the population.

II INTERPRETATION

Tables 41 and 42 are extracted from Canadian hospital morbidity statistics for the year 1980-81. If necessary, these data expressed in absolute numbers may be converted into the number of separations and days per 100,000 population, i.e. into crude rates.

Since stays in hospital correspond to periods of disability for the individual, hospital morbidity can be expected to indicate the principal causes of changes in the mean health of the population. Leaving aside childbirth, the principal causes of hospitalization are also among the principal causes of disability or mortality. Given groups of diseases can be rank-ordered quite similarly using data on mortality, disability and hospital morbidity.

Hospital morbidity statistics are, nevertheless, influenced by selective factors related to the different nature of the various health problems and the care they require. The distinction between out-patient and hospital care varies considerably with the nature of the problem. For example, the concentration of major surgical care in hospitals causes an over-representation of certain conditions in hospital morbidity statistics, in particular in the data on separations.

In addition, these statistics are often influenced by factors exogenous to health status. Among these factors are: availability of care, physical and financial accessibility to care, decisions aimed at limiting the number and length of hospital stays, etc. All this has a considerable effect on the comparability of hospital morbidity data over time and space.

III TECHNICAL DISCUSSION

Canadian statistics are compiled from separation forms supplied by public general and allied special hospitals. Separations are due to death, return to domicile or transfer to another hospital or institution. In these statistics, a given individual is included as many times as separation forms are completed for that person.

TABLE 41. Twelve Leading Causes of Hospitalization by Number of Separations and Days of Hospital Care, by ICD-9 Sub-groups, Males, Canada, 1980-81

Sub-groups of diseases and conditions	Number of separations			Days of hospital care		
	Rank	Number	Per-centage	Rank	Number	Per-centage
42. Ischemic heart disease	1	88,799	5.9	2	1,206,235	6.5
77. Symptoms and nonspecific abnormal findings	2	78,416	5.2	12	487,264	2.6
56. Hernia of abdominal cavity	3	57,653	3.8	–	–	–
51. Other diseases of upper respiratory tract	4	57,606	3.8	–	–	–
50. Chronic obstructive pulmonary disease and allied conditions	5	55,534	3.7	7	600,987	3.2
57. Noninfective enteritis and colitis and other diseases of intestines and peritoneum	6	54,379	3.6	–	–	–
61. Disease of male genital organs	7	50,993	3.4	–	–	–
30. Neurotic disorders, personality disorders and other nonpsychotic mental disorders	8	46,479	3.1	4	694,996	3.7
43. Diseases of pulmonary circulation and other forms of heart disease	9	43,649	2.9	5	682,470	3.7
73. Dorsopathies and rheumatism	10	43,491	2.9	–	–	–
58. Other diseases of digestive system	11	42,021	2.8	9	525,995	2.8
47. Acute respiratory infections	12	41,304	2.8	–	–	–
44. Cerebrovascular disease	–	–	–	1	1,637,944	8.8
29. Organic psychotic conditions and other psychoses	–	–	–	3	950,480	5.1
34. Other disorders of the central nervous system	–	–	–	6	663,942	3.6
45. Diseases of arteries, arterioles and capillaries	–	–	–	8	549,067	3.0
49. Pneumonia	–	–	–	10	500,938	2.7
98. Supplementary classifications	–	–	–	11	494,806	2.7

Source: Statistics Canada, Health Division, Institutional Care Statistics Section.

TABLE 42. Twelve Leading Causes of Hospitalization by Number of Separations and Days of Hospital Care, by ICD-9 Sub-groups, Females, Canada, 1980-81

Sub-groups of diseases and conditions	Number of separations			Days of hospital care		
	Rank	Number	Percentage	Rank	Number	Percentage
67. Delivery	1	348,196	16.8	2	1,861,412	7.7
63. Other disorders of female genital tract	2	119,350	5.8	10	718,213	3.0
64. Complications mainly related to pregnancy and ectopic pregnancy	3	103,305	5.0	–	–	–
77. Symptoms and nonspecific abnormal findings	4	86,959	4.2	–	–	–
98. Supplementary classifications	5	81,478	3.9	7	853,205	3.5
58. Other diseases of digestive system	6	64,230	3.1	11	695,763	2.9
57. Noninfective enteritis and colitis and other diseases of intestines and peritoneum	7	64,057	3.1	–	–	–
66. Pregnancy with abortive outcome less ectopic pregnancy	8	57,048	2.8	–	–	–
51. Other diseases of upper respiratory tract	9	53,393	2.6	–	–	–
30. Neurotic disorders, personality disorders and other nonpsychotic mental disorders	10	53,135	2.6	5	908,576	3.8
42. Ischemic heart disease	11	51,817	2.5	4	1,133,785	4.7
62. Disorders of breast and inflammatory of female pelvic organs	12	41,760	2.0			
44. Cerebrovascular disease	–	–	–	1	2,048,246	8.5
29. Organic psychotic conditions and other psychoses	–	–	–	3	1,315,483	5.5
43. Diseases of pulmonary circulation and other forms of heart disease	–	–	–	6	861,488	3.6
34. Other disorders of the central nervous system	–	–	–	8	799,472	3.3
72. Arthropathies and related disorders	–	–	–	9	726,943	3.0
81. Fracture of lower limb	–	–	–	12	686,994	2.8

Source: Statistics Canada, Health Division, Institutional Care Statistics Section.

I-09: CAUSE-SPECIFIC DEATH RATE

I DESCRIPTION

Definition

Annual number of deaths attributed to a given cause per 100,000 persons in the population under observation (crude rate), or in a standard population subjected, by means of a calculation, to the same mortality conditions (standardized rate).

Descriptive Function

All other things being equal, the number of deaths attributed annually to a given cause depends on the size and age composition of the population. In comparative studies, the crude rate is accordingly used to eliminate the size factor and the standardized rate to eliminate both the size factor and the unequal relative size of age groups in various populations.

Indication Sought

Extent of health problems linked to the development of certain pathological conditions, or brought on by certain outside causes.

II INTERPRETATION

Usefulness of Cause-specific Death Statistics

Due to the well-known insufficiency of morbidity statistics, death statistics by cause are still the only way of obtaining an overall picture of the morbidity experienced by the population. This information is made available at least once a year in countries with a good vital statistics registration system.

In such an overall picture, the frequency of each morbid condition is necessarily weighted by its lethality. A common but rarely fatal disease would be less well represented than another less common but generally more serious disease. The morbidity "spectrum" is thus shifted so as to favour the grave pathological conditions.

This shift is in effect more of a help than a hindrance in determining the principal health problems, since these problems are thus ranked on a scale of severity which is independent of observers. This scale nevertheless does not lend itself to an appreciation of the true impact of certain accidents or diseases which, like for instance mental illnesses, cause few deaths but involve many impairments and disabilities.

It should also be recalled that the cause of death selected by statisticians is the underlying cause, i.e. the one which initiated the sequence of morbid events leading to death (see Chapter 5). This is obviously the cause whose prevention is the most important, which explains its particular interest to public health authorities.

Utility and Limits of Cause-specific Death Rates

The crude death rate from a specified cause gives the number of deaths for a population whose size is held constant over time. This rate is nevertheless sensitive to the age composition of the population, especially if the mortality involved varies considerably with age. The sensitivity of the rate to this demographic factor would be negligible for mortality from accidental causes, but high for mortality attributable to cerebrovascular diseases. In most cases, estimating the importance of a disease from the value of the crude death rate implies that one considers importance to be a function of both the proportion of persons in high-risk age groups and the level of risk.

Although such a point of view is sometimes appropriate, it obviously does not suffice for all health planning requirements. Public health authorities, who obviously have no power over the age distribution want to know if variations in a given type of mortality from time to time or from place to place is the result of corresponding variations in risk. To determine this, they control for the effect of differences in age composition by calculating standardized death rates for the cause in question.

If they are interpreted with caution (see technical discussion), major variations in the standardized death rate are highly significant for public health. Since the age factor is eliminated, these variations cannot be explained by factors exclusively related to human biology. The explanation must be sought elsewhere: degree of exposure to risk factors of the disease, frequency and promptness of consultation, availability and accessibility of preventive care and treatment, effectiveness of such care and treatment. Evaluation of the probable role of each of these determining factors will provide guidelines for planning future public health programs.

The standardized rate, like the crude rate, is nevertheless hampered by certain limitations which restrict its use as an indicator:

1. it combines all deaths attributed to a given cause, even though those occurring at advanced ages would appear to be difficult to avoid,

2. it gives the same weight to all these deaths, while the impact of a death is greater the earlier in life it occurs.

The effect of these limitations may, of course, be reduced by calculating standardized rates which exclude mortality among very old persons. However, this is an imperfect solution, and it is usually preferable to turn to other indicators, the best known of which is "potential years of life lost" (see I-15).

III TECHNICAL DISCUSSION

Calculation of Rates

Calculated for a one year reference period, the death rate from a given cause is obtained by multiplying by 100,000 the ratio of the number of deaths attributed to that cause during the year to the total population at mid-year (Table 43). When the calculation is made for a period of several years, the ratio is that of the number of deaths during the period to the sum of the total populations in the middle of the years making up the period; the objective being to preserve an annual dimension in the rate.

The standardized death rate from a given cause is calculated according to a method identical to that used for the standardized death rate itself (see I-02, Technical Discussion). The only difference is the number of deaths used: deaths from a given cause in one case, and total deaths in the other.

Comparability of Rates

Comparability of rates calculated at different periods or for different areas may be affected by differences in the classification of deaths by cause. Before comparing rates, one must therefore ascertain whether there is homogeneity in the methods of declaring, selecting and classifying causes of death.

It should also be mentioned that, for small populations, the rates obtained may be marred by fairly large random fluctuations. In such cases, the use of statistical tests will enable significant differences to be distinguished from those which could be due to chance alone.

TABLE 43. Calculation of Cause-specific Death Rates, by Sex and Age, Using the Example of Tumours,[1] Canada, 1976

Age group	Males			Females		
	Number of tumour deaths	Population	Rate (per 100,000)	Number of tumour deaths	Population	Rate (per 100,000)
	(1)	(2)	$(3)=[(1)/(2)]\text{x}10^5$	(4)	(5)	$(6)=[(4)/(5)]\text{x}10^5$
0 years	11	177,690	6.2	6	168,855	3.6
1- 4 "	54	710,950	7.6	33	674,505	4.9
5- 9 "	69	966,730	7.1	52	921,080	5.6
10-14 "	65	1,164,645	5.6	48	1,111,730	4.3
15-19 "	97	1,195,975	8.1	58	1,149,280	5.0
20-24 "	110	1,065,770	10.3	68	1,068,040	6.4
25-29 "	114	1,000,520	11.4	86	992,540	8.7
30-34 "	130	822,690	15.8	150	804,795	18.6
35-39 "	198	671,340	29.5	264	657,450	40.2
40-44 "	385	643,575	59.8	397	624,640	63.6
45-49 "	719	630,475	114.0	784	622,370	126.0
50-54 "	1,282	595,715	215.2	1,215	624,465	194.6
55-59 "	1,837	492,260	373.2	1,505	526,775	285.7
60-64 "	2,616	435,785	600.3	1,891	469,615	402.7
65-69 "	3,029	338,520	894.8	1,948	382,300	509.5
70-74 "	3,152	241,365	1,305.9	1,990	292,360	680.7
75-79 "	2,565	150,430	1,705.1	1,885	212,275	888.0
80-84 "	1,851	85,250	2,171.3	1,559	135,310	1,152.2
85 years and over	1,399	59,835	2,338.1	1,505	104,695	1,437.5
All ages	**19,683**	**11,449,520**	**171.9**	**15,444**	**11,543,080**	**133.8**

[1] ICDA, 8th revision, code numbers 140-239.

Source: Statistics Canada, **Causes of Death, 1976**, Catalogue 84-203, p. 33 and Statistics Canada, **1976 Census of Canada**, Catalogue 92-823, Table 11.

I-10: PROBABILITY OF EVENTUALLY DYING FROM A SPECIFIED CAUSE

I DESCRIPTION

Definition

Proportion of persons dying from the cause in question in a cohort subjected to the mortality conditions prevailing in the population at large.

Descriptive Function

Since people do not die from the same causes at different ages in life, distribution by cause of all the deaths observed during a period is influenced by the age composition of the population. The effect of this interference may be eliminated by calculating this distribution for deaths occurring in a cohort hypothetically subjected to the same mortality conditions. The probabilities resulting from such a calculation would allow one to determine the true distribution of deaths by cause that is associated with the observed level of mortality.

Indication Sought

Relative importance of a specific health problem, as seen in terms of its contribution to the total deaths ultimately experienced by members of a cohort.

II INTERPRETATION

By way of illustration, Table 44 shows the probability of dying from certain causes under the mortality conditions prevailing in Canada and the United States in the 1970s. Of particular note is the predominant place that is now occupied by circulatory ailments and tumours among all causes of death.

These probabilities must obviously be considered when wanting to know the distribution of deaths by cause which is in effect associated with a given mortality level. The distribution by cause which is actually observed will differ more or less from these probabilities, depending on the age composition of the population.

A more thorough examination of the cause-specific mortality structure would require a breakdown of these probabilities by age. This will not be done here; however, details of this procedure will be given in the technical discussion.

Such probabilities may be used in weighting qualitative arguments with respect to the choice of priorities in the public health field. In most cases, however, the indicator used for this purpose combines these probabilities with the mean number of years of life lost per person deceased (see I-14).

III TECHNICAL DISCUSSION

Information Required

To calculate the probability of dying from a specific cause, the following must first be known:

(a) statistics of observed deaths by sex, age and underlying cause of death,

(b) the general life table for the same reference period.

TABLE 44. Percentage of Persons in a Birth Cohort Dying from Various Causes, by Sex, United States (1969-71) and Canada (1970-72 and 1975-77)

ICDA code (8th revision)	Cause of death	Males			Females		
		United States 1969-71	Canada 1970-72	Canada 1975-77	United States 1969-71	Canada 1970-72	Canada 1975-77
		percentage					
140-239	**Neoplasms**	**17.2**	**19.5**	**20.7**	**16.3**	**18.2**	**18.8**
150-159	Neoplasms of digestive system and peritoneum	4.8	6.8	6.5	5.1	6.9	6.7
160-163	Neoplasms of respiratory system	5.2	5.3	6.3	1.3	1.1	1.6
174	Neoplasms of breast	–	–	–	3.0	3.4	3.5
390-458	**Diseases of the circulatory system**	**56.4**	**53.4**	**52.0**	**63.2**	**59.4**	**58.2**
410-414	Ischemic heart disease	39.1	35.4	34.2	38.2	33.0	32.2
430-438	Cerebrovascular diseases	9.5	9.6	8.9	15.1	14.9	14.2
E800-E999	**Accidents**	**7.9**	**7.8**	**7.5**	**4.2**	**4.5**	**4.3**
E810-E823	Motor vehicle accidents	2.8	2.8	2.3	1.2	1.2	1.0
E800-E807 and E825-E949	Other accidents	3.0	3.4	3.2	2.1	2.5	2.4
001-999	**ALL CAUSES**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Calculated from vital statistics data for the United States (1969 to 1971) and Canada (1970-1972 and 1975-1977); United States. DHEW. **United States Life Tables: 1969-71** (U.S. Decennial Life Tables, Vol. I, 1), Washington, U.S. DHEW, 1975, 29 p.; and Statistics Canada, **Life Tables, Canada and Provinces** (1970-1972 and 1975-1977), Catalogue 84-532.

Sequence of Calculations

Once a cause has been selected, one first calculates for each sex, and at each age, the proportion of deaths attributed to that cause.

Using this proportion, one then calculates the corresponding number of deaths in the life table. At each age, life table deaths are thus broken down by underlying cause in the same way as observed deaths.

All the life table deaths attributed to the cause in question are then added and the sum of these deaths is divided by the number of survivors at birth to obtain the probability of dying from this cause. Table 45 provides an example.

Disaggregation by Age

Using the same procedures as just described, it is possible to calculate the "probability for a person of age x of eventually dying from the specified cause". From the life table deaths attributed to this cause, retain only those which occurred after birthday x and calculate the ratio of these deaths to the number of survivors on that birthday. From table 45, the probability for a man of 65 to ever die from cancer would be 0.205: (i.e. 14,611 divided by the number of survivors at age 65 in the life table, or 71,385).

It is also possible to calculate the "probability of dying from a specified cause in a given age interval" by taking the ratio of life table deaths attributed to this cause in the age interval considered to the number of survivors at the beginning of this interval. The data in Table 45 show that the probability of a Canadian male dying from cancer before age 65 is 0.06044 or 6,044 per 100,000.

TABLE 45. **Calculation of the Probability of Eventually Dying from a Specified Cause, Males, Canada, 1975-77**

Age	Proportion of deaths attributed to tumours (per 1,000)	Life table deaths (all causes)	Deaths attributable to tumours	Deaths attributable to other causes
	(1)	(2)	(3) = (1) x (2)	(4) = (2) - (3)
0 years	3.9	1,481	6	1,475
1- 4 years	90.8	310	28	282
5- 9 years	169.5	168	28	140
10-14 "	122.9	228	28	200
15-19 "	55.2	705	39	666
20-24 "	52.6	886	47	839
25-29 "	76.4	732	56	676
30-34 "	117.4	743	87	656
35-39 "	132.8	1,005	133	872
40-44 "	175.0	1,551	271	1,280
45-49 "	208.2	2,525	526	1,999
50-54 "	241.8	3,942	953	2,989
55-59 "	262.6	5,940	1,560	4,380
60-64 "	271.7	8,399	2,282	6,117
65-69 "	265.4	11,124	2,952	8,172
70-74 "	254.4	13,729	3,493	10,236
75-79 "	223.1	15,057	3,359	11,698
80-84 "	183.0	14,174	2,594	11,580
85 years and over	127.9	17,301	2,213	15,088
Total		**100,000**	**20,655**	**79,345**
Probability		**1**	**0.207**	**0.793**

Source: Calculated from Statistics Canada, **Vital Statistics**, Vol. IV, Causes of death, Catalogue 84-203 (1975 to 1977) and Statistics Canada, **Life Tables, Canada and Provinces, 1975-1977**, Catalogue 84-532.

Property of the Indicator

When they are calculated for the same age interval and the causes of death chosen are mutually exclusive, the probabilities thus obtained are additive, since they have the same denominator (i.e. the number of survivors at the beginning of the interval), and their numerators are the number of deaths which may be added together without risk of double-counting.

It becomes interesting to consider the sum of these probabilities when the causes chosen for the calculation involve all deaths to be divided into mutually exclusive groups. This sum is then necessarily equal to the probability of dying in the age interval chosen, for a person still alive at the beginning of that interval. It follows that the sum is equal to 1.0 when the probabilities of eventual death are added, since death is inevitable.

I-11: CUMULATIVE RISK OF DYING FROM A SPECIFIED CAUSE

I DESCRIPTION

Definition

Probability of dying before a given age in the absence of all other causes of death.

Descriptive Function

To the multiplicity of underlying causes of death corresponds a multiplicity of competing risks to which the individual is exposed throughout life. Competition between these risks means that the number of deaths attributed to a specific cause is less than that which would result from complete exposure to the risk attributed to this cause alone. By treating deaths imputed to other causes as disruptive events which limit the duration of exposure to the risk under study, it is possible to calculate this one risk and thus describe each particular type of mortality independently of the others.

Indication Sought

Impact of a specified health problem, considered over the entire life cycle.

II INTERPRETATION

In evaluating the impact of a cause of death from the number and proportion of deaths attributed to it, one is observing an actual situation which results in great part from interference between the various causes of mortality. This number and this proportion thus cannot be dissociated from the context of overall mortality. All other things being equal, the decline in communicable diseases has, for instance, enabled a greater number of persons to remain exposed for a longer period to the risk of death from chronic diseases, contributing to an increase in the number and proportion of deaths attributed to these latter diseases.

This means that only a combination of the risks observed for this one cause of death at each age can provide a specific indicator of each individual type of mortality. Such a combination may easily be obtained through the life table method. In this way, a risk of death can be calculated over a very long age interval, while eliminating the interference that exists between the various types of mortality.

In Table 46, the cumulative risks of death between birth and age 85 have been calculated, for the principal causes of death. These risks indicate, for a given cohort, what would be the proportion of persons who would die from the cause in question before age 85 if this were the only cause of death. In this way, the impact of each type of mortality is correctly measured independently of all the others.

Insofar as the notion of risk is now generally understood, this indicator lends itself better to developing public awareness of certain health problems than does the annual frequency by cause of death. Thus, expressing excess male mortality in terms of relative risks seems more suggestive than a simple difference between two annual death rates. By using the notion of risk, for instance, the public has been made aware of the danger to health of certain living habits.

By making it possible to grasp the impact of a health problem for the life cycle as a whole, the cumulative risk of death may also aid in defining goals for long-term health policies. By varying the upper and lower age limits cumulative risks can be calculated for phases in the cycle which correspond to various objectives.

TABLE 46. Risk of Dying before Age 85 by Cause and by Sex, United States (1969-71) and Canada (1970-72 and 1975-77)

ICDA code (8th revision)	Cause of death	Males			Females		
		United States 1969-71	Canada 1970-72	Canada 1975-77	United States 1969-71	Canada 1970-72	Canada 1975-77
		Per 100					
140-239	**Neoplasms**	**29.5**	**30.8**	**31.7**	**19.3**	**20.4**	**20.0**
150-159	Neoplasms of digestive system and peritoneum	9.8	12.3	11.5	6.6	8.4	7.7
160-163	Neoplasms of respiratory system	9.5	9.1	10.8	1.7	1.4	1.9
174	Neoplasms of breast	–	–	–	3.8	4.1	4.0
390-458	**Diseases of the circulatory system**	**69.5**	**63.4**	**60.9**	**52.0**	**46.4**	**42.4**
410-414	Ischemic heart disease	55.7	48.4	46.0	36.4	30.0	27.1
430-438	Cerebrovascular disease	19.3	17.4	15.4	16.0	14.6	12.6
E800-E999	**Accidents**	**10.6**	**9.8**	**9.2**	**4.6**	**4.4**	**4.2**
E810-E823	Motor vehicle accidents	3.6	3.5	2.9	1.4	1.4	1.2
E800-E807 and E825-E949	Other accidents	4.4	4.4	4.2	2.3	2.2	2.1

Source: See source, Table 44.

III TECHNICAL DISCUSSION

Since the cumulative risk is calculated using the life table for the cause in question, this discussion will begin with a presentation of this table and an explanation of how it is computed.

Life Table for a Specified Cause

Table 47 shows the series of probabilities, survivors and deaths from an abridged male life table for deaths due to tumours or neoplasms. It may be seen that:

- the number of survivors diminishes with age only through the accumulation of the deaths shown in the table,
- deaths in an age interval are equal to the product of the probability of death multiplied by the number of survivors at the beginning of the interval.

The relationships between probabilities, survivors and deaths are thus entirely identical to those of an ordinary life table.

Apart from this similarity of form, there is of course a basic difference between the two tables, which results from the different nature of the risk of death considered. In a life table for deaths due to tumours, one would not use the total risk of death as is done in general life tables, but only the specific risk attributable to tumours. The survivors and deaths shown in Table 47 are consequently those which would be obtained in a synthetic male cohort whose members were subjected from birth on to the risk of death from tumours alone.

Probability of Death from a Specified Cause

The deaths and survivors in a life table for deaths due to a specified cause depend only on the size of the synthetic cohort at birth and the series of death probabilities for that cause. Computing such a table is thus entirely based on the calculation of these probabilities. How are such probabilities calculated?

TABLE 47. Life Table for Deaths Due to Tumours,[1] Males, Canada, 1975-1977

Age X	L(X)	D(X,X+A)	Q(X) per100,000
0 years	100,000	6	5.7
1 year	99,994	29	28.6
5 years	99,966	29	29.1
10 "	99,937	29	28.6
15 "	99,908	40	39.8
20 "	99,868	48	48.2
25 "	99,820	58	58.4
30 "	99,762	91	91.7
35 "	99,670	141	141.5
40 "	99,529	290	291.6
45 "	99,239	572	576.4
50 "	98,667	1,067	1,081.2
55 "	97,600	1,823	1,868.0
60 "	95,777	2,851	2,977.0
65 "	92,926	4,085	4,396.4
70 "	88,841	5,655	6,365.8
75 "	83,185	6,948	8,352.4
80 "	76,237	7,908	10,372.9
85 "	68,329	68,329	100,000.0

1 All tumours, i.e. codes 140-239 in the ICDA, 8th revision.
Source: See Source, Table 45.

A first method is based on a prior breakdown of general life table deaths by underlying cause of death. Once this breakdown is obtained, using the method presented in the technical discussion of Indicator I-10, one has the following information for each age interval:

S = number of survivors at the beginning of the interval in the general life table,
D_1 = number of deaths in that table attributed to the cause under study,
D_2 = number of deaths attributed to other causes.

Designating as Q_1 the risk of death attributable to the cause in question, the number of expected deaths in the age interval considered may be calculated as SQ_1. This number is greater than D_1 because persons dying from other causes (D_2) are subtracted from the number exposed to the risk during the second half of the interval. Assuming that the persons dying from other causes were neither more nor less exposed than others to the risk attributable to the cause under study, one may formulate:

$$D_1 = SQ_1 - \tfrac{1}{2} D_2 Q_1$$

Probability Q_1 may thus be obtained using Formula (1), the application of which is shown in Table 48.

$$Q_1 = D_1/(S - \tfrac{1}{2} D_2) \qquad (1)$$

TABLE 48. Calculation of Probability of Male Death from Tumours Using the First Formula, Canada, 1975-77

Age	S	D_2	$(S - \frac{1}{2} D_2)$	D_1	$Q_1 = D_1/(S - \frac{1}{2} D_2)$
50 years	89,666	2,989	88,171	953	0.010809
55 "	85,724	4,380	83,534	1,560	0.018675
60 "	79,784	6,117	76,725	2,282	0.029742

In most cases, however, probability Q_1 is calculated using the general death probability Q and the proportion f_1 of deaths attributed to the chosen cause; this is done using the formula:

$$Q_1 = 1 - (1 - Q)^{f_1} \qquad (2)$$

This second formula is felt to be preferable to the first insofar as, in conformity with the assumed independence of risks, it permits the probability of survival (1-Q) to be obtained by simply multiplying the complements of the death probabilities for the various causes of death, which is not always the case when these probabilities have been obtained using the first formula. Table 49 is an illustration of this second method.

TABLE 49. Calculation of Probability of Male Death from Tumours Using the Second Formula, Canada, 1975-77

Age	Q	1-Q	f_1	$(1 - Q)^{f_1}$	$Q_1 = 1 - (1 - Q)^{f_1}$
50 years	0.043963	0.956037	0.2418	0.98919	0.01081
55 "	0.069292	0.930708	0.2626	0.98132	0.01868
60 "	0.105272	0.894728	0.2717	0.97023	0.02977

These two methods of calculating death probabilities from a given cause are not absolutely identical. In a recent detailed analysis of their respective theoretical foundations, situations were described where application of the two methods leads to different results.[12] In practice, however, the results obtained are generally similar for the great majority of causes and ages. This does not, however, mean that they are correct, since both methods are based on the hypothesis of independence between the risk attributable to the cause under study and the equivalent risk for other causes. This hypothesis is quite questionable, especially at older ages. Although this difficulty has been recognized for some time, few authors have attempted to overcome it.[13]

Calculating the Cumulative Risk of Death

Once the life table has been computed, the cumulative risk of death from birth to age x is calculated by dividing the total life table deaths between birth and age x by the size of the cohort at birth.

From Table 46, the cumulative risk of death from tumours before age 85 would then be 0.317 for Canadian males.

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12 Le Bras, H. and Artzrouni, M., "Interférence, indifférence, indépendance", **Population** 35, 6, November-December 1980, pp. 1123-1141.

13 Damiani, P., "Méthodes de calcul d'une table de mortalité non accidentelle", **Bulletin trimestriel de l'Institut des actuaires français**, 87,204, March 1976, pp. 29-52.

I-12: PREVALENCE OF DISABILITY BY CAUSE

I DESCRIPTION

Definition

Measurement of the frequency of types of disability in the population by the cause to which they are attributed.

Descriptive Function

For a greater or lesser length of time, and to a greater or lesser extent, disease (or accident) alters the ability of its victims to lead a normal life by making it difficult or impossible for them to perform the basic actions of daily life and carry out their usual activities. The frequency of these types of disability is a measure of the impact of disease prevalence on the everyday life of a population.

Indication Sought

Alteration of the positive health of the population resulting from the prevalence of a given disease.

II INTERPRETATION

Perceived Morbidity and Resulting Disability

In discussing the prevalence of perceived morbidity (see I-07), it was seen that this prevalence is high even if the institutionalized population is not taken into account. Self-reported health problems often do not appear to be serious, however, since many of them do not bring about the types of behaviour characteristic of persons who feel ill. In order to obtain a more realistic picture of the health status of a population, the perceived morbidity must then be weighted according to the severity of the various health problems.

This severity is normally expressed in terms of disability. Statistics available in many countries, including Canada, permit the severity of a health problem to be characterized using four proportions calculated for the total number of persons suffering from this problem:

1. proportion of persons who have experienced one or more days of disability during the past two weeks,

2. proportion of persons obliged to restrict their principal activity because of this health problem,

3. proportion of persons obliged to be inactive because of this problem,

4. proportion of persons institutionalized because of this problem.

This reveals the point prevalence of various types of disability in the population suffering from a specific health problem.

To illustrate this, the centre column of Table 50 shows the prevalence of restriction of activity in the non-institutionalized Canadian population. It will be seen that this type of disability affects more than 41% of persons with cardiac problems and almost 35% of those who have been injured. Conversely, many problems that are very common in the population only rarely cause limitation of a person's principal activity.

TABLE 50. Prevalence of Health Problems and Resulting Activity Limitation, Canada, 1978-79

Type of health problem	Number of problems per 10,000 population	Number of cases of activity limitation per 100 problems	Number of cases of activity limitation per 10,000 population
	(1)	(2)	(3) = [(1)x(2)]/100
Mental disorders	434.3	12.6	54.7
Diabetes	164.6	10.6	17.4
Thyroid disorders	129.0	0.3 (males)	–
Anemia	181.1	3.1[1] (females)	–
Headache	478.7	1.0[1] (females)	–
Sight disorders	521.2	6.0	31.3
Hearing disorders	446.5	3.3[1]	14.8
Hypertension	673.7	4.9	33.0
Heart disease	367.9	41.1	151.2
Acute respiratory ailments	339.2	–	–
Influenza	295.4	–	–
Bronchitis and emphysema	244.1	9.8	23.9
Asthma	237.6	17.7	42.1
Hay fever and other allergies	936.9	1.3	12.2
Dental trouble	737.1	–	–
Gastric and duodenal ulcers	209.4	2.5[1] (males)	–
Digestive disorders	298.4	6.8	20.4
Skin disorders	896.5	–	–
Arthritis and rheumatism	1,059.8	11.4	120.7
Limb and joint disorders	1,013.7	22.1	224.1
Trauma	267.6	34.9	93.4
Others	1,155.3	24.2	279.3
TOTAL	**11,087.2**	**10.4**	**1,156.2**

[1] Margin of error falls between 20% and 39%.

Source: Canada. Health and Welfare Canada and Statistics Canada. **The Health of Canadians: Report of the Canada Health Survey**, Supply and Services Canada, Ottawa, 1981, p. 118.

The last column in Table 50 gives the prevalence of activity limitation as calculated by taking the ratio of the number of cases of disability to the total size of the population; this latter figure includes all persons, whether or not they suffer from the health problem mentioned. This new prevalence, which is the one normally shown in current publications, is equal to the product of the preceding (column 2 in the table) multiplied by the prevalence of the health problem in question (first column). It allows pathological conditions to be ranked while taking into account both their prevalence in the population and the frequency of their disabling effects.

Table 51 gives the five main causes of disability by type, still for the non-institutionalized Canadian population. Because they are quite common and often give rise to temporary disability, certain acute health problems are at the top of the list of causes responsible for disability days.

Looking only at long-term disability, however, chronic ailments top the list. Since the health of an individual is mainly defined as a lasting state, it is the causes of long-term disability which are normally given priority.

TABLE 51. The Five Main Causes of Disability by Type, Canada, 1978-79

Disability days	Activity Limitation	Inactive due to health problems
Influenza	Limb and joint disorders	Limb and joint disorders
Acute respiratory ailments	Heart disease	Arthritis and rheumatism
Trauma	Arthritis and rheumatism	Heart disease
Limb and joint disorders	Trauma	Hypertension
Heart disease	Mental disorders	Mental disorders

Source: Canada. Health and Welfare Canada and Statistics Canada, **The Health of Canadians: Report of the Canada Health Survey**,Supply and Services Canada, Ottawa, 1981, pp. 116 and 118.

Disability Indicators and Mortality Indicators

Having estimated the impact of a pathological condition on the actual mean health of the population, one can attempt to calculate its effects on the duration and quality of the average life. Tables 52 and 53 show these estimates for Quebec.

The figures in these tables might be made clearer by use of an example. If diseases of the circulatory system ceased to be fatal before age 75, life expectancy for men would increase by 4.32 years. If they only ceased to be disabling, life expectancy in good health for men would rise by 2.34 years. The sum of these two gains, i.e. 6.66 years, is called "total impact".

From a methodological point of view, the interest of these tables resides in the fact that they bring to light deficiencies in both mortality and disability indicators. When looking only at mortality, the indicators do not address health problems as important as musculoskeletal diseases or mental disorders (not including suicide). Similarly, in the case of disability indicators, the true importance of cancer and congenital anomalies is not manifest. Only an indicator that combines disability and mortality would allow health problems to be properly ranked with a view to defining priorities. Such an indicator was recently suggested by Dillard for Quebec.[14]

III TECHNICAL DISCUSSION

Sources of Information

The most complete data come from surveys on a representative sample of the population living in private households. The 1978-79 survey of the health of Canadians is a good example (see the technical discussion of I-04). The data furnished by such surveys must, however, be augmented by equivalent information on persons living in institutions if one wishes to know the prevalence of various types of disability in the population as a whole.

[14] Dillard, S., **Durée ou qualité de la vie?**, Québec, Conseil des affaires sociales et de la famille, 1983, 70 p.

TABLE 52. Total Impact[1] of Various Pathological Conditions on Life Expectancy in Good Health, Males, Quebec, 1980

Pathological condition \ Nature of impact	Type of activity restriction: Institutionalized	Permanent	Temporary	Total	Rank	Mortality	Rank	Total impact	Rank
Diseases of the circulatory system	0.21	1.67	0.46	2.34	2	4.32	1	6.66	1
Heart diseases	0.18	1.46	0.40	2.04		3.25		5.29	
Accidents and trauma[2]	0.02	0.59	0.34	0.95	4	1.63	3	2.58	2
Tumors	0.01	–	–	0.01		2.50	2	2.51	3
Diseases of the musculoskeletal system	0.04	2.13	0.36	2.53	1	–	2.53	4	
Arthritis and rheumatism	–	0.61	0.11	0.72		–		0.70	
Diseases of the respiratory system	0.04	0.70	0.78	1.52	3	0.58	5	2.10	5
Bronchitis, emphysema, asthma	–	0.60	0.17	0.77		0.17		0.94	
Mental disorders[3]	0.21	0.31	0.02	0.54	5	0.50	6	1.04	6
Congenital anomalies and perinatal defects	–	–	–	–		1.01	4	1.01	7
Diseases of the digestive system	0.04	0.26	0.16	0.46	6	0.44	7	0.90	8
Diabetes	–	0.11	–	0.11	7	0.13	8	0.24	9

1 In years.
2 Not including suicides.
3 Including suicides.

Source: Table 12 in Dillard, S., **Durée ou qualité de la vie** (Collection "La santé des Québécois"), Conseil des affaires sociales et de la famille, Québec, 1983, p. 55.

TABLE 53. **Total Impact[1] of Various Pathological Conditions on Life Expectancy in Good Health, Females, Quebec, 1980**

Pathological condition / Nature of impact	Type of activity restriction: Institutionalized	Permanent	Temporary	Total	Rank	Mortality	Rank	Total impact	Rank
Diseases of the circulatory system	0.53	1.90	0.50	2.93	2	2.73	1	5.66	1
Heart diseases	0.40	1.45	0.31	2.16		1.72		3.88	
Diseases of the musculoskeletal system	0.18	3.70	0.61	4.49	1	–		4.49	2
Arthritis and rheumatism	0.09	1.74	0.29	2.12		–		2.12	
Tumors	0.02	–	–	0.02		2.17	2	2.19	3
Accidents and trauma[2]	0.04	0.80	0.36	1.20	4	0.70	4	1.90	4
Diseases of the respiratory system	0.04	0.46	0.99	1.50	3	0.30	5	1.80	5
Bronchitis, emphysema, asthma	–	0.40	0.06	0.46		0.07		0.53	
Mental disorders[3]	0.31	0.58	0.18	1.08	5	0.20	7	1.28	6
Congenital anomalies and perinatal defects	–	–	–	–		0.86	3	0.86	7
Diseases of the digestive system	0.07	0.09	0.23	0.39	6	0.27	6	0.66	8
Diabète	–	0.22	–	0.22	7	0.14	8	0.36	9

1 In years.
2 Not including suicides.
3 Including suicides.

Source: Table 13 in Dillard, S., **op. cit.**, p. 56.

General population censuses are sometimes used to enumerate certain cases of permanent disability. Up to and including 1951, Canadian censuses provided a great deal of information on the prevalence of blindness and deafness.

There are also registers of persons suffering from long-term disability. Some are very specific, such as that of the Canadian National Institute for the Blind (CNIB), while others are more general, such as the British Columbia Health Surveillance Registry.

Types of Disability

For more details, see the technical discussion of the indicator I-04.

Impact of a Health Problem on Life Expectancies

Mortality due to a given pathological condition reduces life expectancy by a quantity that is calculated using the method described in the technical discussion of Indicator I-14 (Life Expectancy Lost).

Disability due to the same condition reduces life expectancy in good health by a quantity calculated as follows:

1. this life expectancy is first calculated taking into account all causes of disability, using the method described in the technical discussion of Indicator I-04,

2. the same life expectancy is then recalculated taking into account only disability due to other causes,

3. the value obtained in Step 1 is subtracted from that obtained in Step 2.

The values shown in Tables 52 and 53 were obtained in this way.

The combined impact of mortality and disability on life expectancy in good health is obtained by taking the difference between:

1. the value of life expectancy in good health after eliminating both mortality and disability due to the pathological condition considered,

2. the value of life expectancy in good health before this elimination.

This method of calculation allows health problems to be ranked according to their impact on life expectancy in good health. It should therefore be of great interest for health planners.

I-13: FRACTION ATTRIBUTABLE TO A RISK FACTOR

I DESCRIPTION

Definition

Proportion of cases of disease, cases of disability, or deaths which may be attributed to exposure of the population to a given risk factor.

Descriptive Function

The consequences of exposure of the population to a risk factor depend on the proportion of persons exposed and the relative risk at which these persons are placed based on the intensity and duration of exposure. The fraction attributable to a risk factor is the result of combining all these various elements and provides an estimate of the contribution of this factor to the morbidity of the population, its mortality or the prevalence of disability.

Indication Sought

Impact of preventive measures destined to either defend the population against exposure to the risk factor, or to eliminate its health-damaging effects.

II INTERPRETATION

To give a better appreciation of the significance and scope of this indicator, the results obtained for two major risk factors are described below: alcohol consumption and smoking.

Alcohol and Mortality (Table 54)

Chronic alcohol intoxication may lead to death due to the specific mental disorders and organic damage it causes. Alcohol intoxication would then be shown on the death certificate as the underlying cause of death. In such circumstances, all deaths observed are attributable to alcohol, and the attributable fraction is 100%.

Alcohol consumption also contributes to the occurrence of accidents and the development of various non-specific diseases. It has been observed that alcohol users are more frequently victims of accidents and certain diseases than are non-drinkers. Since non-drinkers also die for these same reasons, however, it is only the additional mortality to which drinkers are subject that should be imputed to their addiction.

Excess mortality from cirrhosis of the liver and certain forms of cancer is very high among alcohol users. As a result, the more drinkers there are in the population, the greater will be the number of deaths attributed to these causes, and the greater the fraction of deaths attributed to alcohol. All other things being equal, the attributable fraction will thus rise with the level of alcohol consumption in the population, and will vary from one cause of death to another as a function of the excess mortality of drinkers.

In Canada in 1975-77, a very large majority of adult deaths from cancer of the oesophagus or cirrhosis of the liver was attributable to alcohol. The same was true for more than a third of adult deaths from cancer of the buccal cavity and larynx, traffic accidents and accidental falls.

TABLE 54. Fraction and Deaths Attributable to Alcohol Consumption, by Sex, Canada, 1975-77

Cause of death and ICDA code (8th revision)	Age in complete years	Males			Females		
		Total deaths	Attributable deaths	Attributable fraction (percentage)	Total deaths	Attributable deaths	Attributable fraction (percentage)
Cirrhosis of the liver (571)	15-69	4,815	3,163	65.7	2,015	1,510	74.9
Malignant neoplasm of buccal cavity and pharynx (140-149)	15-69	993	434	43.7	–	–	–
Malignant neoplasm of larynx (161)	15-69	514	185	36.0	–	–	–
Malignant neoplasm of oesophagus (150)	15-69	761	568	74.6	–	–	–
Motor vehicle traffic accidents (E810-E823)	1-69	11,138	4,256	38.2	3,927	1,503	38.3
Deaths due to accidental falls and fires (E880-E899)	15-69	2,331	783	33.6	835	262	31.4
Alcoholic psychosis (291)	1-69	72	72	100.0	14	14	100.0
Alcoholism (303)	1-69	1,405	1,405	100.0	326	326	100.0

Source: Calculated from Statistics Canada, **Vital Statistics**, Vol. IV, Causes of death, Catalogue 84-203 (years 1975 to 1977), following the method proposed by Walter, S.D., **Methodological Developments in the Use of Attributable Fraction for Health Priorities and Strategies in Canada**, Health and Welfare Canada, Ottawa, 1976, 116 p.

Smoking and Mortality (Table 55)

Smoking is not included as one of the underlying causes of death. However, it has been known for almost half a century that smokers do not live as long as non-smokers. Their excess mortality from cancer of the respiratory system, eosophagus, buccal cavity and larynx and from ischemic heart disease is striking. The spread of the smoking habit from one generation to the next has thus contributed, together with other factors, to an increase in the mortality attributed to these various causes of death.

As shown in Table 55, deaths attributed to these various causes in 1975-77 included a high proportion of deaths imputable to tobacco use. Among men, who are heavier smokers than women, the attributable fraction was two-thirds or more for the deaths due to the tumours taken into account here, but only 28% for deaths attributed to coronary diseases.

It should be noted that, in these calculations, only the excess mortality of persons who still smoked has been taken into account. If one had included the excess mortality of former smokers, the attributable fractions would have been higher: in the case of death from cancer of the lung and bronchus, it would rise to 83% for men and 68% for women.

TABLE 55. Fraction and Deaths Attributable to Current Smoking, by Sex, Canada, 1975-77

Cause of death and ICDA code (8th revision)	Age in complete years	Males			Females		
		Total deaths	Attributable deaths	Attributable fraction percentage	Total deaths	Attributable deaths	Attributable fraction percentage
Malignant neoplasm of oesophagus (140-149)	15-69	993	710	71.5	302	99	32.8
Malignant neoplasm of oesophagus (150)	15-69	761	504	66.2	218	104	47.7
Malignant neoplasm of larynx (161)	15-69	514	426	82.9	67	36	53.7
Malignant neoplasm of trachea, bronchus and lung (162)	35-69	10,562	7,119	67.4	3,207[1]	1,569[1]	48.9[1]
Bronchitis, chronic bronchitis and and emphysema (490 - 492)	45-74	3,437	1,897	55.2	–	–	–
Ischaemic heart disease (410 - 414)	40-69	42,951	12,105	28.2	13,562	1,384	10.2
Cerebrovascular disease (430 - 438)	40-69	5,947	837	14.1	4,669	558	12.0

[1] For those 40-74 years of age.
Source: See source, Table 54.

Smoking and Disability (Tables 56 and 57)

Using the 1978-79 survey of the health of Canadians, it has been possible to calculate the annual number of disability days experienced by adults not living in institutions. On the average, this figure is higher for smokers and former smokers than for persons who have never smoked, with the result that 21% of disability among men and 12% of that among women may be attributed to smoking.

Discussion

As the above tables show, the "attributable fractions" allow the many consequences of exposure of a population to a known risk factor to be quantified, whereas this would otherwise be impossible. It is thus possible to make an inventory of the whole range of health problems caused by such exposure: number of deaths, number of cases or days of disability, number of cases or days of illness, etc.

Faced with such results, the researcher and the health practitioner may each react in a different way, as has been demonstrated by Strasser.[15]

The researcher will generally adopt a basically critical attitude. There will first be attempts to determine whether a causal relationship has truly been established between the risk factor and the diseases in question, and it may often be discovered that all the conditions of causal research in medicine have not been satisfied. The researcher will then demonstrate that the additional risks to which exposed persons are subject are not necessarily attributable in their entirety to the risk factor being considered, and that the fraction attributable is thus not always a correct measure of the impact of this factor. Notice also that the sum of the fractions attributable to various risk factors of a given disease is occasionally greater than 100% (see examples of this in Tables 54 and 55). To differing degrees, the results thus established will therefore appear to be uncertain and premature due to deficiencies in current knowledge and to the imperfect nature of the measurement.

TABLE 56. Annual Disability Days Per Person and Per Type of Cigarette Smoker, by Age and Sex, Canada, 1978-79

Age	Sex	Type of cigarette smoker: Total		Never smoked		Former smoker		Current smoker	
		Disability days	Number of persons (thousands)	Disability days	Number of persons (thousands)	Disability days	Number of persons (thousands)	Disability days	Number of persons (thousands)
15 years and over	M	12.9	7,993	11.3	1,984	14.2	2,317	13.2	3,692
	F	21.1	8,271	19.9	3,409	22.2	1,624	22.1	3,238
15-24 years	M	8.8	2,147	7.1	809	7.3	355	10.8	983
	F	12.9	2,154	9.4	749	14.6	409	14.7	996
25-34 "	M	7.5	1,802	10.1	450	5.7	451	7.1	901
	F	19.2	1,826	13.3	630	22.3	438	22.6	758
35-44 "	M	9.2	1,265	13.1	245	9.1	394	7.9	626
	F	18.6	1,261	17.4	449	16.5	255	20.9	557
45-54 "	M	13.2	1,128	6.8	173	14.3	382	14.1	573
	F	21.9	1,127	17.5	441	19.7	222	26.9	464
55-64 "	M	27.4	884	13.5	157	24.8	370	37.6	357
	F	31.2	951	30.8	476	28.2	173	34.1	302
65 years and over	M	25.9	768	37.5	150	26.0	365	20.5	253
	F	35.8	954	33.6	665	53.7	127	32.4	162

Source: Table 1 in Collishaw, N.E., "Disability Attributable to Smoking, Canada, 1978-79", **Chronic Diseases in Canada**, 3, 3, December 1982, p. 62.

Thus the health practitioner will be obliged to adopt a highly pragmatic attitude given the incomplete information available and the immediate responsibilities of the position. Insofar as the likely effect of a risk factor will seem to be adequately confirmed by a combination of assumptions drawn from epidemiological studies and laboratory tests, these tabulations will be seen as a valuable aid in decision-making. These will provide an estimate of the negative effects on the health status of the population if no action were taken, as well as an estimate of the maximum impact of appropriate preventive measures.

From this point of view, the tabulations drawn up with regard to the consumption of alcohol and tobacco are of great interest:

1. evidence of the harmful effects of alcohol and tobacco has accumulated steadily for the past 20 years or so;

2. these two practices are so widespread that a significant fraction of morbidity, disability and mortality in adulthood may be attributed to each of them;

3. this attributable fraction is high for those health problems which have been designated as priorities (ischaemic heart disease, traffic accidents, cancers of the lung and bronchus, cirrhosis of the liver);

4. this attributable fraction is high for diseases that are as yet incurable.

The decision not to act would be difficult to justify, all the more so since the preventive measures to be taken would cost relatively little and would have no negative effects on health.

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[15] Strasser, T., "À propos de l'article de J.L. Richard: Lipides alimentaires, cholestérolémie et cardiophathies ischémiques", **Revue d'Épidémiologie et de santé publique**, 28, 1980, pp. 485-487.

TABLE 57. Disability Due to Current or Former Use of Tobacco among Males and Females Ages 15 to 64, Canada, 1978-79

	Males			Females		
	Never smoked	Current and former smokers	Total	Never smoked	Current and former smokers	Total
Person days per year - disabled state (millions)	17	67	84	46	95	141
Total person days per year (millions)	669	1,968	2,637	1,002	1,669	2,671
Rate of disability days per person	0.0254	0.0340		0.0459	0.0569	
Relative risk		1.35			1.25	
Percentage of total disability days attributable to smoking		20.9[1]			11.8[1]	
Total number of disability days attributable to smoking		17,543,000			19,388,000	
Annual disability days per person attributable to smoking		2.42			2.65	

1 Percentage of total number of disability days attributable to smoking = $\frac{D_{CF} - (T_{CF} \times R_N)}{D_T} \times 100$

D_{CF} = Person days in the disabled state for current and former smokers.
T_{CF} = Total person days for current and former smokers.
R_N = Rate of disability days per person for those who have never smoked.
D_T = Total person days in the disabled state.
Source: Table 2, in Collishaw, N.E., "Disability Attributable to Smoking ...", **op. cit.**, p. 62.

III TECHNICAL DISCUSSION

The details given below are only a brief overview of the calculation of attributable fractions and their properties. Readers who are interested in knowing more about this are advised to consult Walter's very detailed treatment of this question.[16]

Expression of Attributable Fractions

To simplify the discussion, a specific risk factor has been chosen: tobacco use.

1. Dichotomous Treatment

Let us imagine that the size of age group x at the middle of the year of observation is N persons, divided into Np smokers and N(1-p) non-smokers. In addition, let us assume that the death rate among non-smokers is equal to m and that of smokers to mr, r being greater than one. In these conditions, the number of deaths, D, among persons of age x during the year will be:

[16] Walter, S.D., **Methodological Developments in the Use of Attributable Fraction for Health Priorities and Strategies in Canada** (Staff Paper No.76-3, Long Range Health Planning), Health and Welfare Canada, Ottawa, 1976, 116 p.

$$D = N(1\text{-}p)m + Npmr$$

This is equivalent to:

$$D = Nm + Npm(r\text{-}1)$$

If the excess mortality of smokers is due to tobacco use, the term Nm represents the number of deaths attributable to other factors, and the difference between D and Nm is the number of deaths attributable to smoking.

By taking the ratio of deaths attributable to smoking to total deaths, the fraction of mortality attributable to smoking can be obtained:

$$F = (Npm(r - 1))/(Nm + Npm(r - 1))$$

$$\text{or: } F = (p(r - 1))/(1 + p(r - 1))$$

2. Polytomous Treatment

Since the risk of death increases with the quantity of tobacco smoked, the Np smokers may be divided into k distinct classes depending on the level of consumption. Using the same reasoning as above, it may be shown that the attributable fraction is equal to:

$$F = \left(\sum_{i=1}^{k} p_i (r_i - 1)\right)/\left(1 + \sum_{i=1}^{k} p_i (r_i - 1)\right)$$

In this formula, p_i represents the proportion of persons in class i, and r_i the ratio of the death rate of members of this class to that of non-smokers.

Estimating the Attributable Fraction

Vital statistics provide the number of deaths at each age, but not the breakdown of these deaths by exposure to various risk factors. The number of deceased smokers is thus not known, and neither is the number of deceased non-smokers. The fraction of mortality attributable to smoking thus cannot be calculated using available mortality data.

From studies on the use of tobacco, however, the prevalence of smoking in the population can be estimated, i.e. the proportions p and p_i. As the above formulas show, the attributable fraction can be calculated from acceptable estimates of ratios r and r_i, i.e. indices of excess mortality or of the relative risks of death among smokers.

Such estimates are now available. Thanks to epidemiological studies carried out in a number of countries, estimates of the excess mortality of smokers are now available for many causes of death: ischaemic heart disease, cancer of the lung and bronchus, etc. Combining the excess mortality indices provided by these studies with the prevalence of smoking in the population provides an estimate of the fraction of each type of mortality which may reasonably be attributed to smoking.

It is clear that multiplying the deaths from each cause by the corresponding attributable fraction, gives an estimate of the "deaths attributable to smoking". To find the fraction of mortality as a whole that is attributable to smoking, one simply adds up these "attributable deaths" for all pertinent causes and takes the ratio of this sum to total deaths. As Table 58 shows, this total fraction may also be calculated directly, i.e. without bringing into play the various causes of death.

Properties of Attributable Fractions

Attributable fractions are calculated separately for each risk factor: smoking, drinking, etc. Of course, each individual is exposed simultaneously to several risk factors, some known, some unknown. One must then ask oneself, going back to the example of smoking, what might be the effect of these multiple exposures on a measure obtained by pretending to ignore them.

TABLE 58. Calculation of the Fraction Attributable to Smoking, Canada, 1979

	Men aged 25 and over	Women aged 25 and over
Risk r	1.7	1.3
r - 1	0.7	0.3
Proportion p	0.488	0.325
p (r - 1)	0.3416	0.0975
Fraction F	0.2546	0.0888
Total deaths	88,992	67,811
Attributable deaths	22,659	6,024

Source: Collishaw, N.E., "Deaths attributable to smoking - Canada, 1979", **Chronic Diseases in Canada** 3, 1, June 1982, p. 3.

Following Walter (**op. cit.**), the attributable fraction formula has been established assuming that the excess mortality of smokers was due to their use of tobacco. This hypothesis corresponds to reality when smoking is a necessary condition for the manifestation of the harmful effects of exposure to other risk factors, or when exposure of smokers to these other risk factors is identical to that of non-smokers. In these two types of situations, the fraction calculated indicates what impact elimination of smoking would have on the mortality in question.

While certain observed situations are clearly close to one or the other of these two types, this is not true for all. In a significant number of cases, it is observed that smokers and non-smokers are exposed in different ways to other risk factors of disease. The excess mortality of smokers is then the result of two effects: that of smoking and that of unequal exposure to other factors. Depending upon whether smokers are more or less exposed than non-smokers to these other risk factors, the fraction obtained will overestimate or underestimate the impact of the eventual elimination of smoking on the mortality involved.

In addition, it is often observed that the sum of the fractions attributable to the various risk factors of a given disease is greater than one, even when these fractions provide a correct measure of the impact of each factor. The obvious absurdity of such results is the best proof that attributable fractions are non-additive.

I-14: LIFE EXPECTANCY LOST

I DESCRIPTION

Definition

Average number of years of life lost per person due to mortality attributed to a cause of death or a risk factor.

Descriptive Function

This is an attempt to evaluate the importance of a given type of mortality through its effect on mean length of life. This effect depends on the proportion of persons in a cohort who are victims of this type of mortality, the distribution of these persons by age at death and the number of additional years they would have lived if the cause of their death had been eliminated.

Indication Sought

Utility of measures destined to reduce a given type of mortality or of research aimed at this objective.

II INTERPRETATION

Causes of Death and Life Expectancy Lost

In the statistics usually available, each death is attributed to its underlying cause, i.e. that which triggered the morbid process leading to death. As a result, it is also to this underlying cause that are generally imputed the total number of years of life lost because of death.

When speaking of years of life lost, a comparison is implicitly established between the observed situation and a hypothetical situation in which the cause of death would not have come into play. These two situations may be described respectively by a general life table and by a life table from which the cause under study has been excluded. The difference between the figures for life expectancy at birth obtained from these two tables is called here "life expectancy lost".

As may be seen from the figures in Table 59, life expectancy lost as a result of death before age 85, attributed to one or the other of the two principal groups of causes, is less than might have been expected. This is obviously due to the advanced age of the majority of victims of cancer or of a circulatory disease.

In comparison, life expectancy lost by men as a result of accidents appears quite high, since it is only slightly less than that caused by tumours. The explanation is simple: accident victims are on the whole younger and lose on the average more years than do cancer victims; this partially compensates for their smaller numbers (Table 60).

These examples are a good illustration of the sensitivity of the indicator to the probability of dying from a specified cause and to the distribution by age of deaths attributed to that cause. For the same probability of death, taking into account the "age at death" factor has the effect of giving a greater weight to causes responsible for premature death than to those which mainly appear during old age. The resulting hierarchy of causes is thus of greater utility than others in establishing public health priorities.

TABLE 59. Life Expectancy Lost Due to Mortality Attributed to Various Causes, by Sex, United States (1969-71) and Canada (1970-72 and 1975-77)

ICDA code (8th revision)	Cause of death	Males			Females		
		United States 1969-71	Canada 1970-72	Canada 1975-77	United States 1969-71	Canada 1970-72	Canada 1975-77
		in years					
140-239	**Neoplasms**	**2.31**	**2.51**	**2.64**	**2.55**	**2.74**	**2.75**
150-159	Neoplasms of the digestive organs and peritoneum	0.54	0.75	0.72	0.60	0.79	0.75
160-163	Neoplasms of respiratory system	0.70	0.68	0.80	0.23	0.18	0.25
174	Neoplasms of breast	–	–	–	0.52	0.57	0.58
390-458	**Diseases of the circulatory system**	**7.39**	**6.51**	**6.16**	**5.77**	**4.94**	**4.57**
410-414	Ischemic heart disease	4.78	4.19	3.97	3.17	2.56	2.41
430-438	Cerebrovascular disease	0.77	0.76	0.68	1.08	1.04	0.93
E800-E999	**Accidents**	**2.31**	**2.43**	**2.29**	**1.04**	**1.09**	**1.03**
E810-E823	Motor vehicle accidents	0.94	0.96	0.83	0.42	0.42	0.37
E800-E807 and E825-E949	Other accidents	0.76	0.92	0.81	0.33	0.39	0.35

Source: See source, Table 44.

TABLE 60. Breakdown of Life Expectancy Lost, by Sex, Canada, 1975-77

Cause of death	Probability of dying before age 85	Years of life lost for each death	Life expectancy lost
	(1)	(2)	(3) = (1) x(2)
Males			
Malignant neoplasm	0.184	14.35	2.64
Diseases of circulatory system	0.412	14.95	6.16
Accidents	0.070	32.71	2.29
Females			
Malignant neoplasm	0.154	17.86	2.75
Diseases of circulatory system	0.325	14.06	4.57
Accidents	0.033	31.21	1.03

Source: See source, Table 45.

Comparability Over Time and Space

Using this indicator for comparisons over time and space requires a certain amount of caution due to the instability in the determination of the underlying causes of death, and the lack of specificity of the indicator.

Advances in knowledge and improvements in therapy have meant that the identification of underlying cause of death shows a certain instability over time. In addition, for a given period this identification may vary from one country to another in spite of efforts to standardize death certificates at the international level. Statistics showing multiple causes of death would overcome this difficulty by permitting the calculation of life expectancy lost as a result of deaths for which the disease specified had been chosen as either the underlying or the associated cause.[17]

Calculating life expectancy lost is based on a dichotomous division of mortality into that attributed to the specified cause and that due to other causes. Mortality from other causes does, however, influence life expectancy lost in two different ways:

1. it partly determines the number of persons exposed at each age to the risk of death from the cause specified, and thus the probability of dying from this cause as well as the age distribution of deaths attributed to it;

2. it fixes the average number of years of life lost due to deaths occurring at each age.

This means that life expectancy lost is in effect not specific to the cause under consideration, because it can never be dissociated from the level of mortality attributed to other causes.

As a result, the effect of a given type of mortality on mean length of life varies with circumstances. Thus the secular decline in communicable diseases has contributed to increasing the probability of dying from a chronic disease as well as the average number of years of life lost by victims of such a disease. This is why variations over time and space in life expectancy lost do not necessarily correspond to variations in the risk of death from the cause in question.

Avoidable Causes and Life Expectancy Lost

The notion of life expectancy lost appears to have been introduced by Duvillard in the early 19th century.[18] At that time, he showed that smallpox caused his contemporaries to lose an average of 3.5 years of life out of a possible 32.3 years. Since it had become possible to eradicate this disease by use of the vaccine discovered by Jenner, a case could obviously be made in favour of immediate preventive action. Life expectancy lost thus appeared from the beginning as an indicator of the utility of public health measures.

Following the example of Duvillard, one can attempt to draw up a list of avoidable causes at any given moment in order to calculate life expectancy lost due to death attributable to these causes. Using a list compiled by Rutstein (List A),[19] it can be estimated that avoidable deaths observed in Canada in 1975-77 reduced the life expectancy of men by 3.2 years and that of women by 2.3 years. This is the cost of individual and collective neglect, in terms of average longevity.[20]

On the other hand, a death that is theoretically avoidable according to current epidemiological and medical knowledge is not always avoidable in practice. When decisions must be taken, it is therefore wise to consider the probable sensitivity of the targeted mortality to the proposed measures. The usefulness of these measures could then be demonstrated by calculating life expectancy lost due to the fraction that could be reducible in the targeted mortality.[21]

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17 Manton, K.G. and Stallard, E., "Temporal Trends in U.S. Multilple Cause of Death Mortality Data: 1968 to 1977", **Demography**, 19, 4, November 1982, pp. 527-548.

18 Pressat, R., "Les tables de mortalité en l'absence de certaines causes de décès", **Canadian Studies in Population**, 1, 1974, pp. 61-72.

19 Rutstein, D.D., "Measuring the Quality of Medical Care", **New England Journal of Medicine**, 294, 1976, pp. 582-588.

20 Smith, E.S.O., "Preventable Mortality: The Price of Neglect", **Canadian Studies in Population**, 3, 1976, pp. 73-88.

21 Tsai, S.P., Lee, E.S. and Hardy, R.J., "The Effect of a Reduction in Leading Causes of Death: Potential Gains in Life Expectancy", **American Journal of Public Health**, 68, 10, 1978, pp. 966-971.

Risk Factors and Life Expectancy Lost

Imputing a fraction of mortality to a risk factor is of great interest to public health since, by definition, such a factor may be dissociated from the individual and is potentially controllable. It is a means of calculating the fraction of mortality that could be avoided by appropriate (and effective) preventive measures.

The utility of these measures may also be illustrated by life expectancy lost due to exposure of the population to a given risk factor. Table 61 shows several values calculated for the Canadian population in 1975-77. These results make a strong case in favour of campaigns against smoking and drinking.

TABLE 61. Life Expectancy Lost Due to Deaths Attributable to Certain Risk Factors before Age 70, Canada, 1975-77

Risk factor	Males	Females
Current use of tobacco	2.05	1.05
Past and present use of tobacco	2.21	1.09
Use of alcohol	1.51	1.09

Source: See the sources to Table 54, and Statistics Canada, **Life Tables, Canada and Provinces, 1975-1977,** Catalogue 84-532.

It should, however, be noted that these results are only approximations, since they are calculated using attributable fractions (see technical discussion of Indicator I-13).

III TECHNICAL DISCUSSION

Life Tables Excluding a Given Cause of Death

As an illustration, Table 62 reproduces a life table for males from which death due to tumours has been excluded. This table shows the gradual extinction of a synthetic cohort whose members have only been exposed, from birth to age 85, to risks of death from causes other than tumours.

To compute such a table, death probabilities excluding deaths from tumours are first calculated. Using the same reasoning as for the calculation of probabilities of death from tumours (see the technical discussion for Indicator I-11), probabilities Q_i may then be obtained using the formula:

$$Q_i = 1 - (1\text{-}Q)^{f_i}$$

... where Q is the overall probability of death at a given age and f_i the proportion of deaths attributed to causes other than tumours at that age.

Once the initial size of the synthetic cohort has been chosen, knowing these death probabilities makes it possible to determine step by step the life table deaths and survivors. As in a general life table, the number of survivors only decreases by the number of deaths calculated, and for each age interval these deaths are equal to the product of the probability by the number of survivors at the beginning of the interval. The table normally ends at age 85 due to the lack of precision in selecting underlying causes of death at very advanced ages.

TABLE 62. Life Table Excluding Deaths Due to Tumours, Canada, 1975-77

Exact age x	Survivors L(x)	Deaths D(x,x+a)	Probabilities Q(x) (per100,000)	Life expectancy E(x)
		Males		
0 years	100,000	1,475	1,475.2	72.78
1 year	98,525	282	286.1	72.87
5 years	98,243	140	142.1	69.07
10 "	98,103	200	204.0	64.16
15 "	97,903	667	681.2	59.29
20 "	97,236	841	864.6	54.68
25 "	96,396	678	702.8	50.13
30 "	95,718	658	687.0	45.47
35 "	95,061	875	920.4	40.77
40 "	94,186	1,287	1,366.9	36.12
45 "	92,898	2,020	2,174.9	31.59
50 "	90,878	3,046	3,351.3	27.24
55 "	87,832	4,530	5,157.4	23.10
60 "	83,302	6,482	7,781.7	19.22
65 "	76,820	8,989	11,701.2	15.63
70 "	67,831	11,893	17,533.0	12.37
75 "	55,938	14,652	26,193.7	9.46
80 "	41,286	15,966	38,670.9	6.93
85 "	25,320	25,320	100,000.0	4.73
		Females		
0 years	100,000	1,187	1,187.1	80.16
1 year	98,813	221	223.6	80.12
5 years	98,592	117	118.4	76.30
10 "	98,475	114	115.3	71.38
15 "	98,362	225	229.1	66.46
20 "	98,136	234	238.1	61.61
25 "	97,903	232	237.1	56.75
30 "	97,671	283	289.8	51.88
35 "	97,388	381	390.8	47.02
40 "	97,007	559	575.7	42.20
45 "	96,449	836	867.0	37.43
50 "	95,612	1,172	1,225.7	32.73
55 "	94,440	1,829	1,937.1	28.11
60 "	92,611	2,963	3,199.0	23.62
65 "	89,648	4,982	5,557.1	19.31
70 "	84,667	8,078	9,541.5	15.30
75 "	76,588	12,698	16,580.1	11.65
80 "	63,890	17,971	28,127.4	8.47
85 "	45,919	45,919	100,000.0	5.81

Source: See Source, Table 45.

Years lived are calculated in the same fashion as in the general life table (see the technical discussion of Indicator I-03). Years lived beyond age 85 are, however, normally estimated as the product of the number of survivors at that age by life expectancy at age 85 from the general life table.

Life expectancy at exact age x is obtained by taking the ratio of the total number of years lived beyond that age to the number of survivors at that age.

Life Expectancy Lost

The life table excluding deaths due to tumours necessarily provides a life expectancy at birth that is greater than that shown in the general life table: 72.78 instead of 70.14 years for males. The difference between these two values, 2.64 years, represents life expectancy lost due to mortality attributable to tumours, or the gain in mean length of life that would result from elimination of that type of mortality alone prior to age 85.

This life expectancy lost may also be obtained as follows:

1. using the method presented in the technical discussion of Indicator I-10, calculate for each age the number of deaths from tumours in the synthetic cohort subjected to the mortality conditions prevailing in the population;

2. as before, compute the life table excluding deaths due to tumours in order to determine the average number of years of life lost by cancer cases who die at each age (life expectancies at various ages);

3. next, calculate the total number of years of life lost by multiplying the number of deaths at each age by the appropriate life expectancy;

4. the total of these years of life lost is then divided by the size of the cohort at birth in order to obtain the life expectancy lost.

As may be seen from Table 63, the result obtained (2.66 years) differs little from the previous estimate (2.64 years). This slight difference is only due to some rounding in calculations.

Although the above method is obviously an extra step which is not necessary for the calculation of the indicator, it nevertheless constitutes a valuable tool for analysing the properties of the indicator. Using the formulas in Table 63, total years of life lost (YLL) may be written:

$$YLL = \sum_x D_1(x,x+a) \,.\, E_2(x+\tfrac{a}{2})$$

Provided D_1 designates total deaths from tumours before age 85, and $p_1(x,x+a)$ the proportion of these deaths which occur between birthdays x and x + a, this equation may be written:

$$YLL = D_1 . \sum_x p_1\,(x,x+a) \,.\, E_2(x+\tfrac{a}{2})$$

Life expectancy lost (LEL) would then be equal to:

$$LEL = (D_1/S_0) \,.\, \sum_x p_1(x,x+a) \,.\, E_2(x+\tfrac{a}{2})$$

It can now be seen that the effect of mortality due to tumours on mean length of life depends on the proportion of victims in a cohort and the distribution of these persons by age at death, as well as on their additional number of years of life had tumours been eliminated from the range of causes of death.

TABLE 63. Detailed Calculation of Years of Life Lost Due to Death from Malignant Neoplasm, Males, Canada, 1975-77

Exact age x	Deaths from tumours $D_1(x,x+a)$	Life expectancy (excluding deaths due to tumours) $E_2(x+\frac{a}{2})$	Years of life lost
	(1)	(2)	(3) = (1) x(2)
0 years	6	72.83	436.98
1 year	28	70.97	1,987.16
5 years	28	66.62	1,865.36
10 "	28	61.73	1,728.44
15 "	39	56.99	2,222.61
20 "	47	52.41	2,463.27
25 "	56	47.80	2,676.80
30 "	87	43.12	3,751.44
35 "	133	38.45	5,113.85
40 "	271	33.86	9,176.06
45 "	526	29.42	15,474.92
50 "	953	25.17	23,987.01
55 "	1,560	21.16	33,009.60
60 "	2,282	17.43	39,775.26
65 "	2,952	14.00	41,328.00
70 "	3,493	10.92	38,143.56
75 "	3,359	8.20	27,543.80
80 "	2,594	5.83	15,123.02
Total	**18,442**		**265,807.14**

Source: Calculated from column 3 of Table 45 and column 4 of Table 62.

The above formulas also show that the combined effect of two specific types of mortality is greater than the sum of their respective effects. The number of deaths in each case can, of course, be added together at each age, but these persons would have survived longer if both types of mortality had been eliminated, rather than only one. Life expectancies lost are thus not additive.

Years of Life Lost per Death

The interest of the formulas described above is also that they clearly indicate the method to be followed in calculating the average number of years of life lost per person deceased. The total number of years of life lost (YLL) are simply divided by the total deaths being considered (D_1). In the example, this would yield 14.41. The same result could of course be obtained by dividing life expectancy lost (LEL) by the death probability D_1/S_0.

This average number of years of life lost obviously depends on whether the deaths attributed to a certain cause occur earlier or later in life. It should, however, be emphasized that it also depends on mortality from other causes, since it is this mortality level that determines the life expectancy lost by the deceased at each age.

Implicit Hypothesis

In all of the foregoing, it is implicitly assumed that persons dying from a specified cause were neither more nor less exposed than others to die from another cause. This hypothesis is probably not always a true reflection of reality.

I-15: YEARS OF LIFE LOST

I DESCRIPTION

Definition

Total, or part, of the years of life lost by members of a population who have died from the cause specified during the year of observation.

Descriptive Function

The objective here is to estimate the potential cost of each specific type of mortality in terms of years of life lost by people who are victims of it during the year. This cost depends on the number of victims and how they are distributed by age at death, as well as on the additional number of years of life they would have had if the cause of their death had been eliminated.

Indication Sought

Utility of measures aimed at reducing the type of mortality concerned, or research undertaken with this objective.

II INTERPRETATION

Comments will be made on two indicators currently in use in Canada: loss of life potential and potential years of life lost.

Loss of Life Potential

The concept of the life potential of a population was introduced to demography by Hersch.[22] This is the total number of years of life which remain for persons who are members of the population at a given date. In calculations, the contribution of each person to this life potential is estimated as the life expectancy for a person of that age.

As a first approximation, one can consider that, if a death reduces the size of the population by one unit, it thus reduces the life potential of this population by a quantity equal to the life expectancy of survivors of the same age as the deceased. The "loss of life potential" (LLP) can be seen as the total number of years of life lost obtained by multiplying for each age the number of actual deaths by the life expectancy of survivors.

For example, the results available for Canada have been shown in Tables 64 and 65. These have been obtained by applying to deaths recorded in 1973 and 1980 among persons under age 85 the life expectancies at various ages provided by the 1971 life table.

A table of this type enables causes to be ranked according to the deaths attributed to them and according to the age-specific distribution of these deaths. Of two causes yielding an equal number of deaths, that responsible for the deaths occuring earlier in life will contribute more than the other to reducing the life potential of the population. As in the calculation of life expectancy lost (see I-14), taking into account the "age at death" factor has the effect of giving more weight to causes responsible for premature deaths than to those which appear mainly in old age.

If a death is seen as representing a greater loss for the community when it occurs at a younger age, the chosen objective would be to minimize losses in life potential, and not only number of deaths. Tables 64 and 65 would then help in the choice of priorities regarding the health measures

[22] Hersch, L., "De la démographie actuelle à la démographie potentielle", Geneva, Librairie de l'Université, 1944, pp. 55-129.

TABLE 64. Loss of Life Potential, by Sex, Canada, 1973

Cause of death	ICDA-8	Males			Females			Total		
		LLP[1]	Percentage	Rank	LLP[1]	Percentage	Rank	LLP[1]	Percentage	Rank
Cancer	140-239	292,620	16.1	2	299,884	23.0	1	592,504	19.0	2
Diabetes mellitus	250	19,774	1.1	12	26,736	2.0	10	46,510	1.5	12
Ischaemic heart disease	410-414	413,976	22.8	1	238,544	18.3	2	652,520	20.9	1
Stroke	430-438	86,944	4.8	5	104,252	8.0	3	191,196	6.1	4
Arterial diseases	440-448	31,652	1.7	11	27,101	2.1	9	58,753	1.9	9
Pneumonia	480-486	43,977	2.4	8	37,983	2.9	7	81,960	2.6	8
Chronic bronchitis, emphysema and asthma	490-493, 519.3	41,029	2.3	9	14,962	1.1	12	55,991	1.8	11
Cirrhosis of the liver	571	38,161	2.1	10	19,763	1.5	11	57,924	1.9	10
Congenital mortality	740-759	57,117	3.1	7	56,843	4.4	6	113,960	3.7	6
Perinatal mortality	760-779	104,981	5.8	4	84,510	6.5	4	189,491	6.1	5
Traffic accidents	E810-E819	201,138	11.1	3	83,805	6.4	5	284,943	9.1	3
Suicide	E950-E959	68,642	3.8	6	29,681	2.3	8	98,323	3.2	7
Other		413,660	22.8		282,430	21.6		696,090	22.3	
ALL CAUSES	001-E999	**1,813,671**	**100.0**		**1,306,494**	**100.0**		**3,120,165**	**100.0**	

[1] Loss of Life Potential (LLP) is equal to the summation from 0 to 85 years of age of the number of deaths by cause in age and sex groups during 1973 (Statistics Canada Catalogue 84-203) times the average life expectancy of each age and sex group. Life expectancies are taken from Table 8 in Basavarajappa, K.G. and Lindsay, J., **Mortality Differences in Canada, 1960-1962 and 1970-1972**, Catalogue 84-533, Statistics Canada, Ottawa, 1976, p. 55.

Source: Table 1 in Smith, M.H., "Potential years of life lost", **Chronic Diseases in Canada**, 3, 3, December 1982, p. 60.

TABLE 65. Loss of Life Potential, by Sex, Canada, 1980

		Males			Females			Total		
Cause of death	ICDA-9	LLP[1]	Per-centage	Rank	LLP[1]	Per-centage	Rank	LLP[1]	Per-centage	Rank
Cancer	140-239	339,826	19.6	2	335,526	26.2	1	675,352	22.4	1
Diabetes mellitus	250	17,436	1.0	12	22,071	1.7	10	39,507	1.3	12
Ischaemic heart disease	410-414	386,145	22.3	1	236,895	18.5	2	623,040	20.7	2
Stroke	430-438	73,823	4.3	5	96,375	7.5	3	170,198	5.7	4
Arterial diseases	440-448	29,320	1.7	10	25,319	2.0	9	54,639	1.8	11
Pneumonia	480-486	28,110	1.6	11	26,597	2.1	8	54,707	1.8	10
Chronic bronchitis, emphysema and asthma	490-493, 496	42,954	2.5	8	19,527	1.5	12	62,481	2.1	8
Cirrhosis of the liver	571	37,776	2.2	9	21,245	1.7	11	59,021	2.0	9
Congenital anomalies	740-759	55,302	3.2	7	52,250	4.1	6	107,552	3.6	7
Perinatal mortality	760-779	66,013	3.8	6	52,772	4.1	5	118,785	3.9	6
Traffic accidents	E810-E819	168,361	9.7	3	69,233	5.4	4	237,594	7.9	3
Suicide	E950-E959	91,283	5.3	4	31,410	2.5	7	122,693	4.1	5
Other		397,005	22.9		289,711	22.7		686,716	22.8	
ALL CAUSES	001-E999	**1,733,354**	**100.0**		**1,278,931**	**100.0**		**3,012,285**	**100.0**	

[1] Loss of Life Potential (LLP) is equal to the summation from 0 to 85 years of age of the number of deaths by cause in age and sex groups during 1980 (Statistics Canada Catalogue 84-203) times the average life expectancy of each age and sex group. Life expectancies are taken from Table 8 in Basavarajappa, K.G. and Lindsay, J., **Mortality Differences in Canada, 1960-1962 and 1970-1972**, Catalogue 84-533, Statistics Canada, Ottawa, 1976, p. 55.

Source: Table 2 in Smith, M.H., **op. cit.**, p. 60.

and research which are in accordance with this objective: to control the causes responsible for the greatest losses (cancers, ischaemic heart disease, traffic accidents) and those whose contribution is on the increase (suicide, cirrhosis of the liver, various diseases of the respiratory system).

Potential Years of Life Lost

In an attempt to concentrate even more attention on premature death, one might calculate years of life lost using only those deaths which occurred before a certain age and eventually consider only the years of life lost before this age limit. The indicator "potential years of life lost (PYLL)" is designed to take into account both of these two possibilities and is thus an excellent indicator of premature mortality.

More specifically, the indicator PYLL provides an estimate of the total years of life lost before age 70 by persons deceased between their 1st and 70th birthdays. For each death considered, the duration of life lost before age 70 is defined as the time interval separating death from the 70th birthday. For a given cause, the total potential years of life lost depend only on the number and mean age of its victims between age 1 and age 70.

Table 66 shows some calculations for the period 1950-1978. Potential years of life lost are given per 1,000 persons between ages 1 and 70 in order to facilitate comparisons over time.

TABLE 66. Rate[1] of Potential Years of Life Lost Between Ages 1 and 70 by Selected Causes,[2] Canada, 1950-1978

Year	All causes	Motor vehicle accidents	Ischaemic heart disease	Suicide	Lung cancer	Cirrhosis of liver
			years per 1,000			
1950	84.0	6.0	–	1.9	0.9	0.6
1960	66.6	9.1	–	2.2	1.3	0.8
1970	63.1	10.1	10.3	3.5	1.9	1.2
1972	64.7	11.6	9.7	3.9	2.0	1.5
1974	63.3	11.5	9.6	4.1	2.2	1.7
1976	58.2	9.0	9.0	4.1	2.1	1.7
1978	56.8	8.7	8.4	4.7	2.4	1.6

1 These are standardized rates expressed in years (potential years of life lost) per 1,000 population between ages 1 and 70. The population enumerated on June 1, 1976, has been taken as standard population.

2 For causes of death, the categories used correspond to revisions of the International Classification of Diseases then in use, i.e. 6th Revision for 1950, 7th for 1960 , 8th for 1970 and beyond.

Source: Table 52 in Ableson, J., Paddon, P., and Strohmenger, C., **Perspectives on Health**, Catalogue 82-540, Ottawa, Statistics Canada, February 1983, p. 65.

In spite of a different grouping of causes of death, in particular for neoplasms, this table reveals the same health problems as the preceding one: ischaemic heart disease, traffic accidents, various cancers, suicide, cirrhosis of the liver. The tables do show differences in the relative importance of these problems. Traffic accidents now appear just as important as ischaemic heart disease and perhaps more important than cancer.

Further insight into possible choices of action can be obtained by calculating the potential years of life lost due to deaths attributable to known risk factors. For example, Table 67 gives the results obtained for tobacco and alcohol using deaths for the three years 1975 to 1977. It may be

seen that each of these two factors contributes appreciably to the total potential years of life lost. Of course, the results obtained for various risk factors cannot simply be added together due to the non-additivity of attributable deaths (see I-13), but the relative size of these figures provides a valuable indication of the respective utility of various preventive measures.

TABLE 67. Potential Years of Life Lost Due to Deaths Attributable to Tobacco and Alcohol Use, Canada, 1975-77

Risk factor		Males	Females
Tobacco: current use	No.	270,525	43,173
	%	10.46	3.47
Tobacco: past and present use	No.	296,468	49,893
	%	11.46	4.01
Alcohol	No.	281,784	92,801
	%	10.89	7.45
All causes of death	No.	**2,586,793**	**1,244,980**
	%	**100.0**	**100.0**

Source: See source, Table 54.

Discussion

As opposed to "life expectancy lost" (I-14), the two indicators just discussed take into account the number of deaths **observed**. This is quite legitimate insofar as decisions regarding public health must always be weighted by the number of cases involved. Rather paradoxically, however, these two indicators do not provide correct estimates of the number of years of life lost as a result of these deaths. As will be demonstrated in the technical discussion, the potential years of life lost are greater than the years of life actually lost before age 70, while loss of life potential is less than the years of life actually lost by those deceased before age 85.

III TECHNICAL DISCUSSION

As reported by Romeder and McWhinnie,[23] there are a number of alternative calculations of this indicator; these differ from one another by the way in which years of life lost following a death are calculated, as well as by the selection of deaths.

Years of Life Lost as a Result of a Death

Four methods of calculation have been proposed. These will be presented by increasing order of complexity.

[23] Romeder, J.-M. and McWhinnie, J.R., "Potential Years of Life Lost Between Ages 1 and 70: An Indicator of Premature Mortality for Health Planning", **International Journal of Epidemiology**, Vol. 6, 2, 1977, pp. 143-151.

1. Option A: Difference Between a Predetermined Age Limit and Age at Death

Designating as l the age limit selected and as x the exact age at death, the number of years of life lost is calculated as (l-x) when death occurs before the age limit and as nil when it occurs after the age limit; all these latter deaths are consequently excluded from the calculation.

For a given age at death, the number of years of life lost is the same, no matter what the cause of death. Results obtained for mutually exclusive causes are therefore additive.

For each type of mortality, the average number of years of life lost per deceased person is equal to the difference between the age limit selected and age at death; total years of life lost then depend only on the number and degree of prematurity of the deaths considered.

The choice of an age limit cannot be completely arbitrary, since it determines the volume of years of life lost and their distribution among the various types of mortality. Depending on what objective is being pursued, normative limits such as the end of adulthood, normal age of retirement, etc., would be chosen. The most commonly selected limits are ages 65, 70 or 75.

It should be added that this method necessarily overestimates the number of years of life lost before the chosen age limit, since not all those deceased would have reached the age limit even if this cause of their death had been eliminated. The higher the age limit, the greater the degree of overestimation.

2. Option B: Difference Between Life Expectancy at Birth and Age at Death

At first glance, this option appears to be a specific case of the preceding one, since life expectancy **at birth** serves as the age limit. It nevertheless differs by the fact that this limit varies over time and from one population to another.

3. Option C: Life Expectancy of Survivors

In this option, years of life lost by the deceased are estimated as the average number of years left to live for survivors of the same age, or life expectancy **at age of death**. Since this life expectancy does not depend on cause of death, the results obtained for mutually exclusive causes are additive.

As opposed to the first two options, this option allows the calculation of total years of life lost as a result of all deaths considered, and not only years of life lost before a certain age.

The idea of comparing the fate of the deceased to that of survivors of the same age certainly appears attractive. It should, however, be noted that, by doing this, the number of years of life lost due to each specific type of mortality are underestimated, since the life expectancy of survivors is partially dependent on mortality due to the cause in question after the age considered.

4. Option D: Life Expectancy at Each Age After Elimination of the Selected Cause of Death

This is the option that was adopted in calculating "life expectancy lost" (see technical discussion of Indicator I-14). The observed situation is here compared to a hypothetical situation in which a given cause of death no longer has an effect. The years of life lost as a result of a death attributed to that cause would be estimated as life expectancy at the same age in that hypothetical situation. This is the best way to calculate the number of years of life lost due to each specific type of mortality.

Compared to the other methods, this option does have several practical disadvantages:

(a) it necessitates more preliminary calculations,
(b) the results obtained are not additive,
(c) it is (for the time being?) less well understood by people using the results.

For these reasons, either option A or C is generally preferred.

Selection of Deaths

Depending on the indication sought, only a portion of observed deaths would normally be considered: deaths occuring before and during the active years, deaths considered as premature, etc. For these deaths, one may calculate the total number of years of life lost, or only those years of life lost before a certain age.

The deaths selected are normally classified by underlying cause of death, grouped according to the organ or system involved, or according to the nature of the morbid process. When attributable fractions are known (see Indicator I-13), one may add to these traditional distributions estimates of the deaths which may be attributed to known risk factors.

By modifying the selection of deaths and the method of calculating years of life lost as a result of death, a very wide variety of indicators may be obtained. For illustrative purposes, the two indicators used in Canada are presented here.

Potential Years of Life Lost (PYLL)

This indicator, proposed by Romeder and McWhinnie (**op. cit.**), is calculated as shown in Table 68 (option A). It will be seen that only those deaths occurring between the first and 70th birthdays are taken into consideration, and that the years of life lost as a result of a death are estimated as the difference between age 70 and age at death. The result obtained is an estimate of the number of years of life lost before age 70 by the deceased aged one year and over.

TABLE 68. Calculation of Potential Years of Life Lost and Comparison with Option D (Modified), Males, Canada, 1976

Age group at death	Average age at death x	Deaths from tumours	Option A		Option D modified[1]	
			70-x	PYLL	Average years lost before age 70	PYLL before age 70
	(1)	(2)	(3)	(4)=(2)x(3)	(5)	(6)=(2)x(5)
1- 4 years	3.0	54	67.0	3,618.0	62.44	3,371.76
5- 9 "	7.5	69	62.5	4,312.5	58.07	4,006.83
10-14 "	12.5	65	57.5	3,737.5	53.17	3,456.05
15-19 "	17.5	97	52.5	5,092.5	48.39	4,693.83
20-24 "	22.5	110	47.5	5,225.0	43.74	4,811.40
25-29 "	27.5	114	42.5	4,845.0	39.07	4,453.98
30-34 "	32.5	130	37.5	4,875.0	34.32	4,461.60
35-39 "	37.5	198	32.5	6,435.0	29.58	5,856.84
40-44 "	42.5	385	27.5	10,587.5	24.89	9,582.65
45-49 "	47.5	719	22.5	16,177.5	20.29	14,568.51
50-54 "	52.5	1,282	17.5	22,435.0	15.78	20,229.96
55-59 "	57.5	1,837	12.5	22,962.5	11.35	20,849.95
60-64 "	62.5	2,616	7.5	19,620.0	6.93	18,128.88
65-69 "	67.5	3,029	2.5	7,572.5	2.36	7,148.44
TOTAL		**10,705**		**137,495.5**		**125,640.68**

[1] The number of years of life lost before age 70, per death occurring before that age, is equal to: $E_{2(x)} - \frac{S_{70} \cdot E_{2(70)}}{S_x}$, with $E_{2(x)}$ being the life expectancy at age x and S_x the number of survivors at age x, in the life table excluding deaths due to tumours.

Source: See the sources to Table 45, and the life table excluding deaths due to tumours (Table 62).

According to the authors, there are two reasons that justify excluding infant deaths. On the one hand, "most cases of infant mortality are due to causes specific to this early period of life and often have a different aetiology than death later on" (**op. cit.,** p. 148). On the other hand, estimating at nearly 70 years the number of years of life lost as a result of such a death appears excessive when one considers that a child dying at a very early age is often replaced by another infant, who then owes its life to the first. Infant mortality is consequently excluded from this calculation because of its specific nature and of the difficulty of estimating its cost to society.

The upper age limit is set at age 70. While the authors state that this choice inevitably involves an arbitrary element, they attempt the following partial justification: "in choosing a cut-off age above 70 one should consider that determination of the underlying cause of death becomes difficult, particularly for very old people. On the other hand, age 65, proposed by several authors, appears rather young, since a great proportion of people are still productive at this age" (**op. cit.,** p. 147).

The number of years of life lost as a result of a death is determined here using Option A and is thus erroneous. The calculations performed by the authors on 1967 Canadian data clearly show the extent of overestimation of the total years of life lost for each of the ten groups of causes (Table 69). The overestimation would be even greater if the chosen upper age limit had been higher than 70 years. This method of calculation therefore amplifies the effect of each type of mortality on the life potential of the population, as well as the benefit that might be expected if it were eliminated.

If the objective is merely to classify causes of death according to the relative numbers of years of life lost for which they are responsible, it would appear that the method of calculation used here is quite satisfactory. Still looking at Table 69, the years of life lost are overestimated by a proportion that varies little with the cause of death; this means that the relationships between the results obtained are not significantly different from those that would be derived from adjusted results. Although the proposed indicator overestimates the impact of each individual type of mortality, it does enable a classification of causes of premature death through a comparison of their respective effects.

TABLE 69. Potential Years of Life Lost and Percentage of Overestimation, Males, Canada, 1967

Causes of death	PYLL (1-70 years)	Corrected PYLL (1-70 years)	Percentage of over-estimation
Infectious diseases	10,200.0	9,235.1	10.4
Neoplasms	124,290.0	114,916.0	8.2
Allergic, endocrine and blood	14,310.0	12,980.9	10.2
Nervous system	41,517.0	37,928.7	9.5
Circulatory system	192,554.5	182,229.6	5.7
Respiratory system	33,139.5	30,259.5	9.5
Digestive system	29,962.5	27,108.2	10.5
Genito-urinary system	8,784.0	7,953.7	10.4
Accidents	308,147.0	283,457.5	8.7
All other causes	29,429.5	27,125.7	8.5
TOTAL	**792,334.0**	**733,194.9**	**8.1**

Source: Romeder, J.-M., and McWhinnie, J.R., **op. cit.**, p. 147.

Loss of Life Potential (LLP)

This indicator, used by Health and Welfare Canada in some of its publications,[24] differs from the above by the selection of deaths and the method of calculating years of life lost as the result of a death.

As may be seen from the calculation of the indicator (Table 70), all deaths occurring before age 85 are included here. In addition, as per Option C, duration of life lost by the deceased is estimated as the life expectancy of survivors of the same age. The result obtained is accordingly an estimate of the total years of life lost by persons deceased from the selected cause before having reached age 85.

In this case, there is an underestimate. Elimination of a cause of death would increase life expectancy at each age, and so the life expectancies used are lower than the actual length of life lost by victims of that cause. The result is necessarily an underestimate of the total years of life lost (Table 70). The relative size of this underestimation is nevertheless generally low, except for those groups of causes responsible for a large proportion of deaths.

[24] Smith, H., "Potential years of life lost", **Chronic Diseases in Canada**, 3, 3, December 1982, pp. 59-61.

TABLE 70. Calculation of Loss of Life Potential and Comparison with Years of Life Lost According to Option D, Males, Canada, 1976

Age group at death	Mean age at death x	Deaths from tumours	Life expectancy at age x E(x)	Loss of life potential (Option C)	Life expectancy at age x (excluding deaths due to tumours) $E_{2(x)}$	Years of life lost (Option D)
	(1)	(2)	(3)	(4) = (2)x(3)	(5)	(6) = (2)x(5)
0 years	0.5	11	70.22	772.42	72.83	801.13
1- 4 "	3.0	54	68.37	3,691.98	70.97	3,832.38
5- 9 "	7.5	69	64.02	4,417.38	66.62	4,596.78
10-14 "	12.5	65	59.11	3,842.15	61.73	4,012.45
15-19 "	17.5	97	54.38	5,274.86	56.99	5,528.03
20-24 "	22.5	110	49.83	5,481.30	52.41	5,765.10
25-29 "	27.5	114	45.24	5,157.36	47.80	5,449.20
30-34 "	32.5	130	40.55	5,271.50	43.12	5,605.60
35-39 "	37.5	198	35.89	7,106.22	38.45	7,613.10
40-44 "	42.5	385	31.33	12,062.05	33.86	13,036.10
45-49 "	47.5	719	26.96	19,384.24	29.42	21,152.98
50-54 "	52.5	1,282	22.83	29,268.06	25.17	32,267.94
55-59 "	57.5	1,837	19.02	34,939.74	21.16	38,870.92
60-64 "	62.5	2,616	15.55	40,678.80	17.43	45,596.88
65-69 "	67.5	3,029	12.45	37,711.05	14.00	42,406.00
70-74 "	72.5	3,152	9.75	30,732.00	10.92	34,419.84
75-79 "	77.5	2,565	7.45	19,109.25	8.20	21,033.00
80-84 "	82.5	1,851	5.54	10,254.54	5.83	10,791.33
TOTAL		**18,273**		**275,154.90**		**302,778.76**

Source: See source, Table 45 and the life table excluding deaths due to tumours (Table 45).

Crude Rate and Standardized Rate

The foregoing two indicators provide absolute figures that are difficult to compare over time and space. All other things being equal, these figures depend on the size and age composition of each population.

The size factor may be eliminated by a calculation similar to that of the crude death rate. For each type of mortality, the total years of life lost are divided by the size of the population to obtain the number of years of life lost per 10,000 or 100,000 population.

The effect of unequal age composition of populations may be eliminated by following the method for calculating the standardized death rate. In this case years of life lost are not calculated using deaths observed in the population, but rather the "expected" deaths in a standard population hypothetically subject to the same mortality conditions (see technical discussion of I-02). By dividing this new total of years of life lost by the size of the standard population, one obtains the standardized rate.[25]

It should, however, be noted that the value of the standardized rate is partially dependent on the age composition of the standard population. Therefore, if the stated intention is to seek an index which depends only on the age and cause structure of mortality, it would be preferable to use life expectancy lost or its derivatives (years of life lost as a result of deaths obtained by subjecting throughout their lives the 100,000 members of a synthetic cohort to observed mortality conditions).

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[25] For an example of the calculation of crude rates and standardized rates of PYLL, see Romeder, J.-M. and McWhinnie, J.R., **op. cit.**, pp. 144-146.

CHAPTER 8

INDICATORS SPECIFIC TO CERTAIN STAGES OF THE LIFE CYCLE

The indicators introduced in the last two chapters were synthetic indices which normally cover the entire life cycle. The ones to be presented now deal only with certain periods of life.

Indicators relative to the period surrounding birth will be considered first. One of these, the infant mortality rate, is often used as an indicator of the health level of the population. In countries where mortality is low, however, preference is increasingly given to the perinatal mortality rate and one of its components, early neonatal mortality. Low birthweight, a risk factor common to all these types of mortality, will also be examined as a health indicator.

Life expectancy by marital status will then be discussed in an attempt to determine whether differences observed are due to the events experienced or to the new conditions of life that they bring about.

The index of excess male mortality is also of interest here: this excess mortality is present at all stages of life, and its magnitude varies with age.

I-16: INFANT MORTALITY RATE

I DESCRIPTION

Definition

Ratio for a given year of deaths among infants under a year old to the number of live births.[1]

Descriptive Function

When the number of births is stable or varies only little from year to year, as is most often the case, or when available statistics allow the rate to be calculated for a cohort, one is in a situation where the infant mortality rate is in effect a probability. For the newborn infants of a given cohort, it represents the probability of dying before their first birthday.

Indication Sought

The infant mortality rate has long constituted a particularly good indicator of hygiene and health conditions prevailing in a population.

The sharp drop in mortality during the first year of life, which is mainly attributed to the near-disappearance of infectious diseases, has however brought about a growing concentration of deaths in the first days of life, thus creating increased interest in care during the perinatal period. In countries with low death rates, the infant mortality rate has gradually given way to the perinatal mortality rate, or even to the early neonatal mortality rate, as an indicator of health care levels (see Figure 18).

Due to its sensitivity to milieu-related factors, the infant mortality rate nevertheless remains a useful indicator in countries with low mortality. For instance, it points out categories of the population with particularly unfavourable living conditions. In international comparisons, it can be used to evaluate countries from the standpoint of their overall level of economic and social development.[2]

II INTERPRETATION

Level and Trends

Two centuries ago, there were 250 deaths under age one per 1,000 live-born infants, whereas in 1981 this rate was 9.6 per 1,000, or a reduction by a factor of 26 (Table 71).

Mortality during the first year of life is very sensitive to social conditions, and it is obvious that improvement in living conditions has played a large part in this development. The contribution of medicine since the turn of the century should not, however, be overlooked. Considerable progress was achieved, for instance, when use of antibiotics became widespread, during the 1940s and 1950s, as well as more recently as a result of perinatal programs.

Although the risk of infant death has dropped sharply, it should be noted that these risks are still relatively high. Around 1981, the risk of dying over a 12-month period was as high at birth as at age 56 for men and age 61 for women.

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1 See technical discussion for other methods of calculating this rate.

2 See Newland, K., "Infant mortality and the health of societies", **World Health Forum**, Vol. 3, 3, 1982, pp. 321-324.

Figure 18

Stillbirths and Infant Mortality

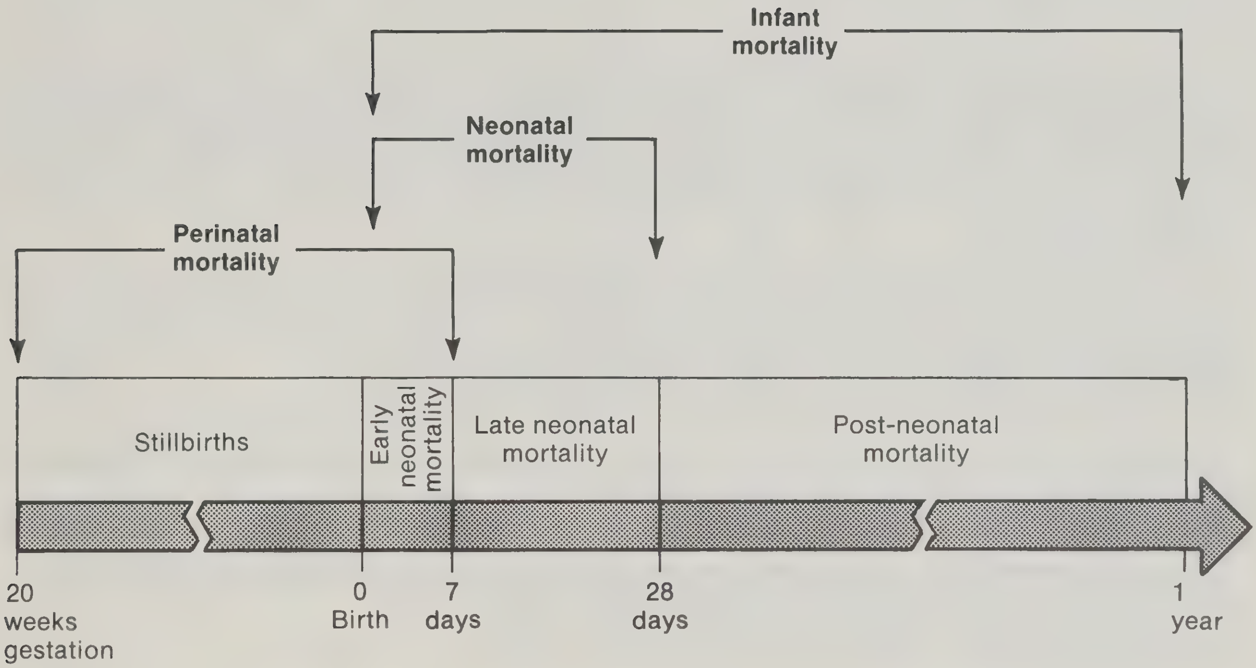

TABLE 71. Infant Deaths, Infant Mortality Rate and Age-specific Distribution of Infant Deaths, Canada, 1931, 1956 and 1981

Year	Infant deaths		Percentage distribution of deaths by age			
	Number	Rate[1]	Less than 7 days	7-27 days	28 days and over	Total
1931[2]	20,360	86.0[3]	34.1	14.6	51.4	100.0
1956	14,399	31.9	52.3	10.7	37.0	100.0
1981	3,562	9.6	57.2	9.0	33.8	100.0

1 Per 1,000 live births.
2 Excluding Newfoundland, Yukon and Northwest Territories.
3 Including Newfoundland, Yukon and Northwest Territories.

Source: Statistics Canada, **Vital Statistics, 1977** (Vol. III), Catalogue 84-206, March 1980, Tables 20, 22, 27, 29 and 30; and Statistics Canada, **Vital Statistics, 1981** (Vol. I), Catalogue 84-204, February 1983.

It should be emphasized, following Sullerot, that this drop in infant mortality:

..."has done more to change the life of human societies that any other demographic phenomenon" ... "It has brought about a radical change in the equilibrium between life and death, including quantitative effects (the rapid growth of the population involved) and qualitative effects (the change in fertility patterns, the induced effects on parental roles, sex roles, etc.) which have been of the greatest importance. All calculations show that the chances of survival of an infant in the first year of life have more effect on the average duration of life than variations, however large, which may occur at later ages."[3]

Causes of Infant Deaths[4]

It has become customary, as recommended by the demographer Bourgeois-Pichat, to distinguish between two main categories of causes:[5] endogenous causes and exogenous causes. The first category of deaths is attributable to diseases stemming from the newborn's constitution, while the second includes external factors such as accidents, communicable diseases or malnutrition. Causes of death which are exclusively endogenous or exogenous are, of course, rare, but this is a convenient distinction.

It should also be recalled that, contemporaneous with the drop in infant mortality, there was a concentration of deaths in the first days of life, but also a change in the nature of causes: formerly due mainly to exogenous causes, infant mortality has become essentially endogenous, since medical intervention has been particularly effective against the first type of factors.

Table 72 gives an idea of the distribution of infant deaths for Canada, by the categories mentioned above. In 1971-72, endogenous mortality represented 75% of infant mortality and, for all categories considered, mortality was higher among males.

[3] Sullerot, E., **La démographie de la France. Bilan et perspectives**, Paris, La documentation française, 1978, p. 69.
[4] For this section, see the study by Henripin, J., **La mortalité infantile au Canada de 1956 à 1972**, Document No. 23, Economic Council of Canada, Ottawa, February 1975, 68 p.
[5] Bourgeois-Pichat, J., "An Analysis of Infant Mortality", **Population Bulletin** (New York, United Nations), No. 2, October 1952, pp. 1-14.

TABLE 72. Infant Mortality Rate[1] by Category of Causes, Canada, 1971-72

Category of causes of death	Both sexes	Males	Females
Endogenous cause	12.9	14.4	11.3
Exogenous causes (excluding accidents and violent deaths)	2.7	3.1	2.3
Accidental and violent causes	0.9	1.1	0.7
Unclassifiable causes	0.9	1.0	0.7
Total infant mortality	**17.3**	**19.5**	**15.1**

[1] Per 1,000 live births.
Source: Table 1 in Henripin, J., **op. cit.**, p. 10.

Factors of Infant Mortality

In 1980, over half the infant deaths in Canada occurred during the week following birth, and almost two-thirds during the first 28 days. It is thus clear that the risk factors and risk markers which influence neonatal mortality are also important with respect to infant mortality.

Table 73, obtained through data linkage, shows variations in the infant mortality rate by certain key variables in the 1971 birth cohort.

TABLE 73. Infant Mortality Rate by Age of Mother and Selected Birth Characteristics, 1971 Birth Cohort, Canada[1]

	Age of mother at childbirth						
	All ages	Less than 20 years	20-24 years	25-29 years	30-34 years	35-39 years	40 years and over
	deaths per 1,000 live births						
Total	**16.5**	**22.7**	**16.7**	**14.2**	**14.8**	**16.2**	**22.4**
(N)[2]	(349,256)	(40,453)	(124,263)	(108,785)	(48,763)	(20,362)	(6,100)
Birthweight and total birth order[3]							
≥2 500 g	7.0	9.2	7.4	5.9	6.1	7.5	11.9
<2 500 g	129.3	152.3	130.8	123.4	123.8	109.3	128.7
<2 500 g and birth order 1	118.0	133.0	108.4	114.7	122.5	157.6	127.7[4]
" " 2	136.3	192.6	143.7	120.1	112.2	102.3	192.3[4]
" " 3	131.4	274.2	160.7	117.2	101.7	113.6	53.6[4]
" " 4 and more	142.5	550.0[4]	189.7	150.5	142.6	99.8	131.2
Mother's marital status							
Married	15.4	20.0	15.8	13.7	14.3	16.2	22.8
Not married	27.2	27.6	27.1	29.3	29.6	16.8	16.9

1 Excluding Newfoundland.
2 Number of live births.
3 i.e. taking into account stillbirths.
4 Less than 10 infant deaths.
Source: Statistics Canada, Health Division (unpublished data).

As has been seen, the level of infant mortality is sensitive to socio-economic conditions. As the relative importance of exogenous deaths (i.e. those related to environmental factors) increases as one moves further from the time of birth, trends in excess mortality shown in Table 74 can easily be understood (the index used gives a measure of infant mortality among the least privileged occupational class, i.e. unskilled workers, using the level of mortality in the professional class as a baseline).

TABLE 74. Index of Excess Infant Mortality in Children of Unskilled Workers Compared to Professionals, England and Wales, 1970-72

Type of mortality	Excess mortality index[1]
Early neonatal (0-6 days)	192
Late neonatal (7-27 days)	249
Post-neonatal (1-11 months)	421
Infant (0-11 months)	**255**

[1] Professionals = 100.

Source: From Table 3.13 in Black, D., **Inequalities in Health: Report of a Research Working Group**, Department of Health and Social Services, London, 1980, p. 85.

III TECHNICAL DISCUSSION

Traditional Calculation

The infant mortality rate, which is the ratio of deaths under age one to the number of births during the same year, is not strictly speaking a rate, since that would assume that the denominator is an average population. It should be noted that this "rate" is, in addition, neither a proportion nor a probability.

Although the calculation shown above is simple and the data required easily available, certain precautions are necessary when making international comparisons, due to differences in the definition of the various categories[6] and the existence of variations in the method of calculation.

The distinction between stillbirth and livebirth is an example of this problem of definition. Thus, in France, "false stillbirths" form a separate category in statistics; these are infants born alive but who died before the time of registration. This designation is explained by the fact that these infants are classified among the stillborn. Proper calculation of the infant mortality rate requires that these false stillbirths first be added to the number of live births and to the number of deaths under age one. In the case of French statistics for 1954, this adjustment led to an infant mortality rate of 40.7 per 1,000, as opposed to 36.5 per 1,000 when false stillbirths were excluded from the calculation.[7] This illustrates the importance of determining what type of rate is being used before making comparisons over time and space.

[6] Höhn, C., "Les différences internationales de mortalité infantile: illusion ou réalité?", **Population**, 36, 4-5, July-October 1981, pp. 791-815.

[7] See Pressat, R., **L'analyse démographique**, 2nd Edition, Paris, P.U.F., 1969, pp. 130-131.

It should be noted that, when the number of births is stable or varies only slightly from year to year, the rate defined is a good reflection of the level of mortality during the first year of life, but, when there is a marked downward trend in the number of births, the rate obtained will be an overestimation, since a fair number of the deaths counted come from births in the previous year. Conversely, a major increase in births from one year to the next brings with it an underestimation of infant mortality.

Other Methods of Calculation

There are other methods of calculating the infant mortality rate, and the choice mainly depends on the type of data available.[8]

It will be recalled that, in the traditional calculation of the infant mortality rate, only part of the deaths included originate from births shown in the denominator; in the case illustrated by Figure 19, the rate would then be 3,464/361,216 = 9.6 per 1,000. However, when there is, as is the case in Canada, a double classification of deaths under age one, a more refined calculation can be done, where the rate would be the sum of two ratios:

$$(459/360{,}377) + (3{,}005/361{,}216) = 9.6 \text{ per } 1{,}000$$

The advantage of the latter calculation is that it takes into account differences in the size of the two cohorts at the time of birth. If mortality is the same for both cohorts, the result is actually an annual probability of death at age 0. The value of this is generally quite close to that of the infant mortality rate which results from the traditional method of calculation, that is, from data for a single calendar year.

If this double classification of deaths is not available, the weighted mean method is sometimes used, where the ratio is calculated of deaths to a weighted mean of the two relevant birth cohorts. The weights used are proportions of the deaths for a given cohort that occur on the one hand during the calendar year of birth and on the other hand during the following year. In the case of Canada, 0.9 and 0.1 are acceptable weights. The rate thus calculated would be:

$$(3{,}464) / (360{,}377 \times 0.1 + 361{,}216 \times 0.9) = 9.6 \text{ per } 1{,}000$$

It should be noted that use of the weighted mean method is declining since, contrary to the trend in the past, most infant deaths now occur in the same calendar year as the birth.

When deaths under age one have been linked to the births from which they come, one may calculate, for individuals of a given birth cohort, the **probability of dying before age one**. The advantage of such a linkage is that, in calculating the probability, only those deaths linked to births in the denominator are included in the numerator. However, certain events (migration in particular) which occur between birth and the time of death, generally cause this number of deaths to be incomplete, leading to an underestimation in the probability thus calculated.

Life Tables for the First Year of Life

These are tables limited to the period of infancy and containing a special breakdown by age: the first year of life is divided into months (1/12 of a year), the neonatal period into weeks and the

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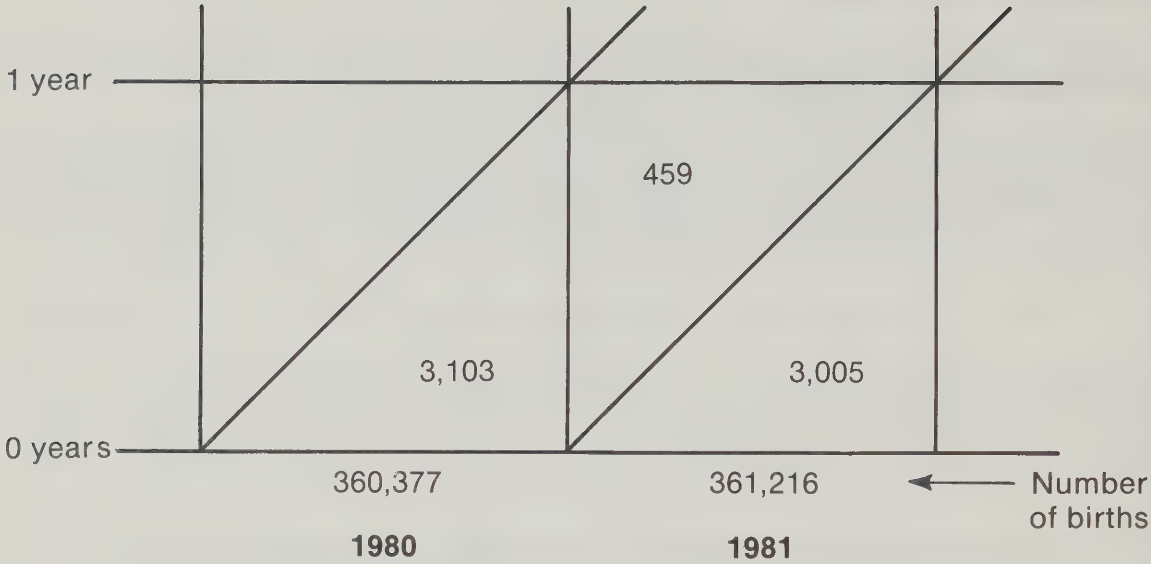
[8] For more details, see Pressat R., **op. cit.**, pp. 130-134; W.H.O., **Manual of Mortality Analysis. A Manual on Methods of Analysis of National Mortality Statistics for Public Health Purposes**, Geneva, W.H.O., 1977, pp. 85-92; and Shryock, H. and Siegel, J., **The Methods and Materials of Demography** (Second printing), Washington, D.C., U.S. Government Printing Office, 1973, pp. 410-415.

Figure 19

Distribution of 1981 Infant Deaths by Year of Birth, Canada (Excluding Newfoundland)



Source: Statistics Canada, Health Division, unpublished data.

early neonatal period into days.[9] The breakdown is finer at points closest to the time of birth. This is because of the particularly high risks encountered during the first days of life. Results are presented in the form of **probabilities of dying** (and not rates).

This type of table is included in the life tables published by Statistics Canada for 1970-72, 1975-77 and 1980-82. Table 75 is taken from these published results. Risks of death will be seen to be very high in the days following birth and to decline sharply with age. It will also be noted that male mortality is higher at all ages.

9 For an example, see Zbořilova, J., "Les tables de mortalité infantile par cause. Application à la Tchécoslovaquie et à la France, 1968-1972", **Population**, 3, May-June 1977, pp. 555-578.

TABLE 75. Life Table for the First Year of Life, by Sex, Canada 1980-1982

Age x	Males: Survivors at age x	Males: Deaths d(x,x+a)	Males: Probability $_aq_x$ (per100,000)	Females: Survivors at age x	Females: Deaths d(x,x+a)	Females: Probability $_aq_x$ (per100,000)
0 days	100,000	402	402	100,000	314	314
1 day	99,598	69	70	99,686	46	46
2 days	99,529	56	56	99,640	41	42
3 "	99,473	35	35	99,599	23	22
4 "	99,438	21	21	99,576	15	16
5 "	99,417	16	16	99,561	12	12
6 "	99,401	14	14	99,549	8	8
7 "	99,387	48	47	99,541	42	42
14 "	99,339	33	33	99,499	23	23
21 "	99,306	21	22	99,476	21	20
28 "	99,285	89	90	99,455	69	70
2 months	99,196	78	79	99,386	53	53
3 "	99,118	60	60	99,333	49	49
4 "	99,058	39	39	99,284	34	34
5 "	99,019	31	32	99,250	21	22
6 "	98,988	20	20	99,229	18	18
7 "	98,968	15	15	99,211	13	13
8 "	98,953	13	13	99,198	13	13
9 "	98,940	10	10	99,185	10	10
10 "	98,930	11	11	99,175	10	10
11 "	98,919	11	11	99,165	8	8
12 "	98,908			99,157		

Source: Adapted from Statistics Canada, **Life Tables, Canada and Provinces, 1980-1982**, Catalogue 84-532, Statistics Canada, Ottawa, May 1984, p. 15.

I-17: PERINATAL MORTALITY RATE

I DESCRIPTION

Definition

Annual number of stillbirths and early neonatal deaths per 1,000 total births.[10]

Descriptive Function

By its method of calculation, the perinatal mortality rate is closer to a probability. It may thus be likened to the risk for fetuses considered viable[11] to be stillborn or to die before the end of their first week of life.

Indication Sought

"Perinatal mortality may be considered as reflecting standards of obstetric and paediatric care as well as the effectiveness of social measures in general and of public health actions in particular. Thus it occupies a key position in determining health policy." [12]

II INTERPRETATION

Level and Trends

Major successes in the battle against mortality have been accompanied by an ever-increasing concentration of deaths at the two extremities of life. At the beginning of the life cycle, neonatal mortality, and especially early neonatal mortality, therefore represents a growing proportion of infant mortality.

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[10] i.e. the total of stillbirths and live births. Also note that, in some calculations, all neonatal deaths are included in the numerator of the rate.

[11] See technical discussion.

[12] W.H.O., "Comparative study of social and biological effects on perinatal mortality", **World Health Statistics Report**, Vol. 29, 1976, pp. 228-234.

TABLE 76. Contribution of Perinatal Mortality to Infant Mortality and Stillbirth: Percentage and Rates, Canada, 1921-1951-1981

	Percentage distribution			Rate	
	Perinatal deaths	Deaths from 7 days to 1 year	Total	Perinatal mortality[2]	Infant mortality[3]
1921	53.7[1]	46.3[1]	100.0[1]	65.2[1]	102.1[4]
1951	64.0	36.0	100.0	35.8	38.5
1981	72.4	27.6	100.0	10.7	9.6

[1] Excluding Newfoundland, Quebec, Yukon and Northwest Territories.
[2] Per 1,000 total births.
[3] Per 1,000 live births.
[4] Excluding Yukon and Northwest Territories.

Source: Statistics Canada, **Vital Statistics, 1977**, Vol. III, Catalogue 84-206, and Statistics Canada, **Vital Statistics 1981**, Vol. I, Catalogue 84-204.

By adding to early neonatal mortality, i.e. that occurring in the first week of life, the stillbirths after 20 weeks of pregnancy, one obtains **perinatal mortality**. There are a number of reasons for combining these two types of mortality. Among these are: the causes of both are related, they generally do not vary independently of one another, and the emphasis placed on prevention focuses attention on the period surrounding birth.

The perinatal mortality rate has become an important indicator of health and, in countries with low mortality, it is increasingly being used in preference to the infant mortality rate. A better understanding of the factors of this type of mortality and its development may be gained by examining causes of death.

Causes of Perinatal Deaths

The utility of cause of death statistics obviously depends on their quality, i.e. how exact and complete they are. Accuracy is governed by factors such as the experience of the certifying physician and the use of post-mortem examination results, when these are performed. In countries which collect these data, however, the proportion of deaths attributed to imprecise or undetermined causes is often quite high.[13]

Uses of data on perinatal mortality is also made difficult by the fact that, until recently, this information was reported on different documents: certificates of birth and of stillbirth for the denominator of the rate, and certificates of stillbirth and of death (early neonatal deaths) for the numerator. The eighth revision of the I.C.D. introduced common classifications for stillbirths and deaths in the first week, thus allowing the causes of perinatal mortality to be grouped. As well, "the introduction of the certificate of cause of perinatal death as recommended .... for the 9th Revision of the I.C.D., in place of the standard certificate of cause of death, should improve the quality of data available...".[14]

Knowledge of causes permits deaths to be divided into two categories: those that are avoidable and those that probably are not. This distinction facilitates the allocation of care and makes it possible to propose a "potential" minimum perinatal mortality rate. This was done by Dr. Usher for Quebec, where this rate was established at 5.6 per 1,000 in 1971-75. It should, however, be noted that this "irreducible" level is not absolute, since it depends, among other things, on the current state of knowledge and on measures implemented, which explains the fact that for 1966-70 it had been calculated to be 9 per 1,000.[15]

It is also important to mention that, in certain cases, a decrease in mortality from a given cause is not a function of a better state of health in the population, but rather an indication of progress in methods used. For example, ultrasonography facilitates early detection of anencephaly, which normally leads to inducing an abortion. Improvement in detection techniques has thus led to the near-disappearance of this cause of death, while also contributing to a decrease in the perinatal mortality rate.[16]

Factors of Perinatal Mortality

According to a W.H.O. report, the level of perinatal mortality is determined by a complex interaction between many biological and social factors.[17]

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13 See W.H.O., "Comparative study...", **op. cit.**, pp. 228-231.

14 W.H.O., "Main findings of the comparative study of social and biological effects on perinatal mortality", **World Health Statistics Quarterly**, Vol. 31, 1978 p. 81.

15 See Usher R., "Clinical implications of perinatal mortality statistics", **Clinical Obstetrics and Gynecology**, Vol. 14, 3, September 1971, p. 920.

16 Personal communication, Dr. R. Usher (Royal Victoria Hospital, Montreal).

17 See W.H.O., **Social and Biological Effects on Perinatal Mortality**, Budapest, Statistical Publishing House, 1978. The salient points of this large-scale study have been discussed in a series of three articles, the most recent being: Foster, F.H., "Trends in perinatal mortality", **World Health Statistics Quarterly**, Vol. 34, 3, 1981, pp. 138-146.

Since most risk factors (use of tobacco, alcohol abuse, malnutrition, etc.) manifest themselves by variations in the incidence of prematurity or fetal malnutrition, it may be suggested that perinatal mortality risks are, on the whole, positively correlated with low-birthweight incidence. The risk factors here are, in fact, the same as those which increase the incidence of low birthweight (see I-19 and Table 77).

Examination of risk markers shows that, as in the case of low birthweight, high-risk mothers are found at both extremities of each distribution. The W.H.O. study mentioned above, which dealt with a number of countries, confirms among other things that in all countries studied high parity and low birthweight are indicators of the mothers most at risk[18] (Table 77). In each country, the level of perinatal mortality depends to a great extent on the proportion of premature births, i.e. those occurring after less than 37 weeks of pregnancy, which corresponds to a particularly high rate of low birthweight (Table 86 in I-19).

TABLE 77. Perinatal Mortality Rate by Birthweight, Parity and Age of Mother, 1971 Birth Cohort, Canada[1]

	Age of mother at childbirth						
	All ages	Less than 20 years	20-24 years	25-29 years	30-34 years	35-39 years	40 years and over
	deaths per 1,000 total births						
Total	**15.4**	**15.6**	**14.4**	**13.7**	**15.9**	**22.8**	**33.4**
(N)[2]	(350,800)	(40,514)	(124,695)	(109,187)	(49,034)	(20,605)	(6,223)
Birthweight and total birth order[3]							
≥ 2 500 g	6.2	4.7	5.5	5.6	7.3	11.1	16.3
< 2 500 g	127.1	124.2	124.8	121.6	125.5	147.1	196.6
< 2 500 g and birth order 1	123.1	114.0	119.2	129.9	137.6	173.1	222.2
" " " 2	117.5	137.6	122.7	109.0	100.0	106.5	245.6
" " " 3	128.0	231.4	134.9	115.5	122.1	130.9	158.7
" " " 4 and over	149.4	470.6[4]	162.0	135.3	136.0	156.6	192.3
Mother's marital status							
Married	14.9	14.0	14.0	13.4	15.2	22.2	33.7
Not married	20.7	18.4	19.1	21.9	38.8	39.5	29.0[4]

1 Excluding Newfoundland.
2 Total number of births (stillborn after 20 weeks of gestation and live-born), 1 000 g and over.
3 i.e. including stillbirths.
4 Less than 10 perinatal deaths.
Source: Statistics Canada, Health Division (unpublished data).

Social inequality may also give rise to differences in perinatal mortality. If for each biological factor (birthweight, length of pregnancy, parity and age of mother), the distributions are fairly similar, less favourable socio-economic conditions are generally associated with lower birthweights, shorter pregnancies, high parity and a greater proportion of births falling outside the optimal range of ages at childbirth.[19] In a large-scale study carried out in Britain, however, one of the conclusions was that differences of class, reflected in this case by occupation, were the real sources of differences in perinatal mortality (which, as shown in Table 78, may vary by a factor of two). The influence of class is not totally explained by maternal age and parity. According to the authors of this report, "there can be no doubt that mothers' health, nutrition and obstetric care received are all class related".[20]

18 W.H.O., "Main findings...", **op. cit.**, pp.75 and 83.
19 W.H.O., "Main findings...", **op. cit.** p. 79.
20 Black, Sir Douglas (Chairman), **Inequalities in Health: Report of a Research Working Group**, Department of Health and Social Security, London, 1980, pp. 171-172.

TABLE 78. Perinatal Mortality Rates by Occupational Class, England and Wales, 1970-72

Sex	Occupational class					
	I professional	II inter-mediate	III skilled		IV partly skilled	V unskilled
			Non-manual	Manual		
	rate per 1,000 total births					
Males	17.4	19.8	22.0	23.2	25.3	33.9
Females	15.2	17.4	19.1	21.0	22.4	30.2

Source: From Table 2.5 in Black, D., **Inequalities in Health..., op. cit.**, p. 34. (For definitions of occupational classes, see pp. 14-15 in the same document.)

Longitudinal and Cross-sectional Approaches

The Norwegian system of medical registration of births, in force since 1967, allowed Bakketeig and Hoffman[21] to link each mother with information available on births during the period 1967-73. The study deals with 417,086 births to 294,534 mothers during that period; this figure excludes fifth order and higher births as well as multiple births.

Using a cross-sectional approach, the authors first calculated perinatal mortality rates by birth order, using aggregated data. The results (last line of Table 79) may be illustrated by the now-familiar U curve.

The mothers were then divided into various categories identified by parity combinations which occurred during the period 1967-73: first order only, first and second order..., third and fourth order, fourth order. The longitudinal approach consisted in calculating for each category of mothers the birth-order specific perinatal mortality rate. It may be observed that, contrary to what happens in cross-sectional analysis, the rate decreases as birth order rises. In addition, for a given birth order, mortality increases as birth order combinations become higher (Table 79). The lowering of rates with successive pregnancies might be explained by a selection phenomenon, where it might be imagined that mothers who had had complications during previous pregnancies are more likely to forego an additional pregnancy. Increases in rates within columns of Table 79 may mask socio-economic differences. It should also be noted that, for higher parities, the interval between successive births should be shorter, the age at childbirth higher, etc.

This brief look at the Norwegian study shows to what extent a strictly cross-sectional approach may be misleading and emphasizes the interest in distinguishing women according to cumulative fertility for studies based on birth order.[22]

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21 Bakketeig, L. et Hoffman, H., "Perinatal mortality by birth order within cohorts based on sibship size", **British Medical Journal**, September 22, 1979, pp. 693-696.

22 For precautions that should be taken when making analyses by birth order, see Magaud, J. and Henry, L., "Le rang de naissance dans les phénomènes démographiques", **Population**, 5, 1968, pp. 879-920.

TABLE 79. Norwegian Perinatal Mortality Rate by Parity for Various Categories of Mothers Defined by Parity Combinations, 1967-73

Category of mothers[1]	Parity 1	2	3	4
	rate per 1,000 births			
Birth order 1	15.6			
Birth orders 1, 2	17.9	9.9		
" 1, 2, 3	55.3	36.1	15.5	
" 1, 2, 3, 4	61.9	62.9	41.9	20.0
Birth order 2		10.2		
Birth orders 2, 3		23.6	13.1	
" 2, 3, 4		45.2	33.4	13.0
Birth order 3			14.1	
Birth orders 3, 4			33.0	17.6
Birth order 4				21.3
Total				
Rates	19.4	14.8	17.0	19.5
Deaths	3,434	2,063	1,245	544

1 Defined according to parity combinations occurring during the observation period.
Source: From Table II in Bakketeig, L. and Hoffman, H., **op. cit.**, p. 694.

Perinatal Mortality as a Health Indicator

An excellent illustration of the **validity** of perinatal mortality as an indicator of care during the perinatal period is given in an article by Dr. Usher.[23] One learns, for example, that in 1971-74 the perinatal mortality rate was 15.2 per 1,000 in the Province of Quebec, which was 60% higher than that prevailing during the same period at the Royal Victoria Hospital in Montreal, which had an intensive care unit suitable for the neonatal period. Another study attributes international variations in the perinatal mortality rate essentially to differences in the measures implemented to protect pregnant women and newborn infants.[24]

The success of the Quebec perinatal program shows to what extent this indicator is **sensitive** to changes in the level of care offered. In effect, the sharp drop in this rate (- 36.5%) between 1967 and 1974 was accompanied by a very slight change in the incidence of low birthweight.[25,26] It would, however, be unfair to attribute the success of perinatal programs in Quebec to differences in the level of care alone, since other changes occurred during the same period. Some of these were demographic (sizeable drop in the number of births to mothers over 35, popularization of contraception and a consequent better spacing of births), some institutional (introduction of medical care insurance, which ensured equal access to quality care to all mothers), and some economic (increased well-being, the effects of which are more difficult to quantify).

23 Usher, R., "Changing Mortality Rates with Perinatal Intensive Care and Regionalization", **Seminars in Perinatology**, Vol. 1, 3, July 1977, pp. 309-319.

24 Höhn, C., "Les différences internationales de mortalité infantile: illusion ou réalité?", **Population**, 36, 4-5, July-October 1981, pp. 791-815.

25 See Usher, R., **op. cit.**, p. 310.

26 Another study, carried out in California, confirms this sensitivity of the indicator: a major portion of the decline in perinatal mortality during the 1970s is attributed to the introduction of intensive care during the neonatal period and to the increase in the proportion of cesarean births. There is, however, considerable controversy surrounding this last explanation. See Williams, R., and Chen, P., "Identifying the Sources of the Recent Decline in Perinatal Mortality Rates in California", **The New England Journal of Medicine**, Vol. 306, 4, January 28, 1982, p. 207.

This indicator is not **specific** insofar as other factors contribute to variation. The influence of the level of care does, however, appear to dominate, as Hellier, for instance, indicates: she claims that most of the decrease in the rate between 1950 and 1973 is due to factors such as mothers' health and the quality of obstetric care.[27]

III TECHNICAL DISCUSSION

It will be recalled that in Canada data on perinatal mortality are regularly compiled by Statistics Canada from two different forms: stillbirth certificates and, for early neonatal deaths, death certificates. Live births also enter into the calculation of the rate.

This type of mortality varies considerably with certain characteristics of the mother. Since these characteristics (age, parity, length of gestation, etc.) only appear on the birth certificate, it is useful to link death certificates with the corresponding birth certificates. In certain countries, this data linkage also allows disaggregation by socio-economic categories.

Comparisons of perinatal mortality levels over time and space are hampered by differences in the criteria used and how these evolve. For example, the definition of viability varies from one study to another, some setting a minimum weight of 1 000 g, others 500 g. In certain cases, the infants selected are those born after 20 or 28 weeks of gestation, or else all those who, whatever their birthweight, gave any sign of life at birth. According to Dr. Usher, these differences may bring about variations in the order of 30% in the perinatal mortality rate.[28]

It should also be added that statistical controls for certain structural factors render these rates more directly comparable accross countries. An example of this is a study which showed that Hungary, in a comparison with six other countries, ranked highest in perinatal mortality. A more detailed analysis however showed that this situation was essentially due to an unfavourable distribution of births by weight in Hungary. When the calculation was done a second time, using a standard distribution of births by weight for each of the seven countries, Hungary had the lowest mortality.[29]

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27 Hellier, J., "Perinatal mortality, 1950 and 1973", **Population Trends**, 10, Winter 1977, p. 15.

28 Usher, R., "Clinical implications of perinatal mortality statistics", **op. cit.**, p. 885. Useful information may also be found in the study by Höhn, C., (**op. cit.**, pp. 800-805), as well as in the section entitled "Variations due to differences in definitions and terminology", in W.H.O., "Comparative study...", **op. cit.**, p. 229.

29 See W.H.O., "Main findings of the comparative study...", **op. cit.**, p. 76.

I-18: EARLY NEONATAL MORTALITY RATE

I DESCRIPTION

Definition

Ratio, for a given year, of deaths in the first week of life to all live births.

Descriptive Function

The early neonatal mortality rate can be considered a probability. It measures, for live-born infants, the risk of dying in the week following birth.

Indication Sought

The risks of early neonatal death constitute an indicator of the level of perinatal care, in particular that delivered during the first week of life.

II INTERPRETATION

The Changing Risk of Neonatal Death

The drop in infant mortality since the turn of the century, due essentially to the near-elimination of infectious diseases, has given a growing relative importance to endogenous deaths and, as a consequence, to those occurring in the first days of existence, which is a particularly high-risk period (Table 80).

TABLE 80. Percentage of Infant Deaths Occurring during the First Week of Life, Early Neonatal Mortality Rate and Infant Mortality Rate, Canada, 1926-1981

Year	Early neonatal deaths (as a percentage of infant mortality)	Mortality rate	
		Early neonatal	Infant
		per 1,000 live births	
1926	33.4[1]	33.0[1]	101.6
1931	34.1[1]	27.9[1]	86.0
1936	37.2[1]	23.9[1]	67.7
1941	37.4[1]	21.7[1]	61.1
1946	43.7[1]	20.0[1]	47.8
1951	46.8	17.7	38.5
1956	52.3	16.5	31.9
1961	58.1	15.6	27.2
1966	62.2	14.2	23.1
1971	62.2	10.8	17.5
1976	58.3[2]	8.2[2]	13.5
1981	57.2	5.5	9.6

1 Excluding Newfoundland, Yukon and Northwest Territories.
2 Excluding Quebec.
Source: Adapted from Statistics Canada, **Vital Statistics, 1977** (Vol. III, Deaths), Catalogue 84-206, March 1980; Statistics Canada, **Vital Statistics, 1975 and 1976** (Vol. I, Births), Catalogue 84-204, November 1978 and Statistics Canada, **Vital Statistics, 1981** (Vol. I, Births and Deaths), Catalogue 84-204, February 1983.

The life table for the first year of life (see technical discussion in I-16) gives a measure of these risks. According to the most recent table, covering 1980-82, 56% of male infant deaths and 54% of female infant deaths occur in the first week of life. These early neonatal deaths are very unequally distributed by age: two-thirds of them take place on the first day, and about 87% before the end of the third day (Table 81). In addition, the probability of dying on the first day of life is over 30 times that of dying on the seventh. Another noteworthy fact is that excess male mortality, which is observable at all ages, exists right from birth, when it involves a 34% difference (see also I-21).

Although all the components of infant mortality have, on the whole, recorded decreases since the turn of the century, this trend did not develop equally for each component. There would appear to be two phases: during the first, early neonatal mortality may be observed to diminish more slowly than infant mortality in general, while during the second phase, which began in the late 1960s, this early neonatal mortality decline becomes more rapid. This means that the relative share of first-week deaths increased until the late 1960s, and has since declined (Table 80).

The foregoing appears to correspond to increased efforts, since the late 1960s, in the areas of contraception and perinatal care, and the extent of these changes would suggest that these efforts have not been in vain. Life tables show that, for the periods 1971-1976 and 1976-1981, the risk of dying during the first week of life dropped by about 30% (Table 82).

Factors of Early Neonatal Mortality

Birthweight is generally considered the best indicator of a newborn's chances of survival.[30] However, to understand the decline in the neonatal mortality rate T and its factors, it is helpful to present this rate as a weighted mean of rates t_x by birthweight x, the weighting factors being the proportions p_x of births of weight x among total live births. Thus:

$$T = \sum_x t_x \cdot p_x \qquad (\text{with } \sum_x p_x = 1)$$

It will be seen later that this breakdown into two elements - the series t_x and the series p_x - facilitates comparisons over time and space. It also helps to bring out the causes of change, since those which influence p_x are different from those that affect t_x.

As shown in Figure 20, which is adapted from Lee, **et al.**,[31] variables such as socio-economic status, age of mother and parity determine, to some extent, birthweight. These variables thus play a role in the incidence of low birthweight[32] (see I-19) but they do not appear to influence t_x. Conversely, perinatal medical care, the sex of the infant and adequate weight for gestational age, are factors associated with the birthweight-specific level of mortality.

The study by Lee, **et al.**, covers the period 1950-1975 in the United States.[33] On the whole, no changes appeared in the distribution of births by weight, in the white population. The neonatal mortality rate, however, dropped sharply, particularly after 1965. Birthweight-specific mortality rates (series t_x) are not available, but examination of trends in factors associated with these rates indicates that, on the one hand, sex-specific distribution of births remained unchanged and, on the other, the proportion of births occurring after a short period of gestation increased, which should have an unfavourable effect of values of t_x. Improvement in medical care thus seems to have played a determining role, and the fact that the greater part of the decrease coincides with a period of major change in perinatal care in the United States supports this claim.

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30 See Lee, K.-S., **et al.**, "The very low birthweight rate: Principal predictor of neonatal mortality in industrialized populations", **The Journal of Pediatrics**, 97, 5, November 1980, pp. 759-764.

31 Lee, K.-S., **et al.**, "Neonatal Mortality: An analysis of the recent improvement in the United States", **American Journal of Public Health**, Vol. 70, 1, January 1980, pp. 15-21. This study actually deals with **neonatal** deaths (0-27 days), but in Canada, for example, 85% of these deaths in 1980 occurred during the first week.

32 It would appear that these variables affect mortality through birthweight and that, within a birthweight category, the socio-demographic factors mentioned have little effect on mortality. See Lee, K.-S., **et al.**, **op. cit.**, p. 19.

33 An identical calculation has since been made for Canada. See Lee, K.-S., **et al.**, "Recent Trends in Neonatal Mortality: The Canadian Experience," **Canadian Medical Association Journal**, Vol. 126, February 15, 1982, pp. 373-376.

TABLE 81. Risk of Early Neonatal Death and Distribution of Life Table Deaths by Sex and Age, Canada, 1975-77 and 1980-82

Age interval x, x + a (in days)	Risk of dying between ages x and x + a								Life table deaths			
	1975-77			1980-82			Variation (1975-77 to 1980-82)		1975-77		1980-82	
	Males	Females	Excess male mortality index	Males	Females	Excess male mortality index	Males	Females	Males	Females	Males	Females
	(1)	(2)	(3)=(1)/(2) x 100	(4)	(5)	(6)=(4)/(5) x 100	(7)	(8)	(9)	(10)	(11)	(12)
	per 10,000			per 10,000			per cent		cumulative percentage			
0-1	57.6	46.9	123	40.2	31.4	128	- 30	- 33	66.1	67.4	65.6	68.4
1-2	10.7	8.4	128	7.0	4.6	153	- 35	- 45	78.3	79.5	76.8	78.4
2-3	8.8	5.9	149	5.6	4.2	135	- 36	- 29	88.4	87.9	86.0	87.4
3-4	3.9	3.4	115	3.5	2.2	158	- 10	- 35	92.8	92.7	91.7	92.4
4-5	2.7	2.3	119	2.1	1.6	130	- 23	- 30	95.9	96.0	95.1	95.6
5-6	1.9	1.6	122	1.6	1.2	133	- 16	- 25	98.0	98.1	97.7	98.3
6-7	1.7	1.3	131	1.4	0.8	186	- 18	- 38	100.0	100.0	100.0	100.0
0-7	87.1	69.6	125	61.3	45.9	134	- 30	- 34	100.0	100.0	100.0	100.0

Source: Calculations made using life tables for the first year of life. See Statistics Canada, **Life Tables, Canada and Provinces, 1975-1977**, Catalogue 84-532, Ottawa, October 1979, p. 13, and Statistics Canada, **Life Tables, Canada and Provinces, 1980-1982**, Catalogue 84-532, Ottawa, May 1984, p. 15.

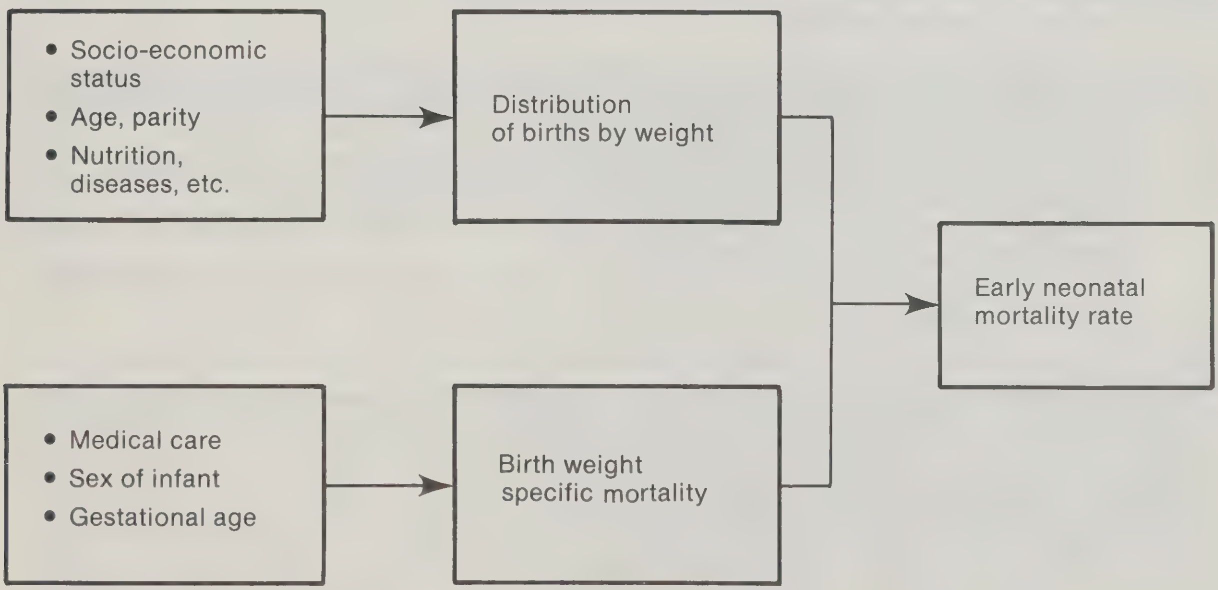
TABLE 82. Per Cent Change in Risk of Death during the First Year of Life, by Sex, Canada, 1971-1976 and 1976-1981

Age in days	1971-1976		1976-1981	
	Males	Females	Males	Females
	Per cent			
0-6	- 31	- 28	- 30	- 34
7 and over	- 18	- 14	- 22	- 23
Total	**- 26**	**- 23**	**- 26**	**- 29**

Source: Calculated from life tables for the first year of life. See Statistics Canada, **Life Tables, Canada and the Provinces**, Catalogue 84-532 (1970-1972, 1975-1977 and 1980-1982).

Figure 20

Main Variables Associated with the Early Neonatal Mortality Rate



Source: Adapted from Lee, K.-S. et al., op. cit., pp. 15-16

A simple calculation makes it possible to estimate the portion of the decline in rates T due to changes in series t_x and that which may be attributed to variations in p_x. This involves calculating, when possible, a second series of rates called "expected" rates T': this is obtained by applying an observed series of rates t'_x (taken from a survey) to the distribution of live births by weight, for each year of observation.[34]

This calculation gives two rates for each year considered:

- the observed rate $T = \sum_x t_x \cdot p_x$
- the "expected" rate $T' = \sum_x t'_x \cdot p_x$

The difference /T'-T/ tells, for a given year, what portion of changes observed since 1950 may be attributed to an improvement in mortality rates by weight category. This approach enabled Lee, **et al.**, to attribute almost all progress in the field of neonatal mortality between 1950 and 1975 to a variation in t_x, whereas, in a study carried out in California (1960-1977),[35] 85% of the improvement was said to be due to this change. In Quebec, where there was a major drop in early neonatal mortality between 1967 and 1974 (- 43%), the contribution of variations in t_x was also the main factor.[36]

Age of Mother and Parity

These two variables deserve particular attention since, because of their role in the incidence of low birthweight (see I-19), their impact on the early neonatal mortality rate is significant, as shown in Table 83 for Canada.

For instance, it has been established that 14% of the decrease in the neonatal mortality rate (0-27 days) observed in the United States between 1950 and 1975 could be attributed to a change in the distribution of live births by age of mother and parity.[37] This result was derived by a standardization calculation, as follows:

- the standardized neonatal mortality rate T'_{75} was calculated. This is done by applying 1950 rates of neonatal mortality (obtained through a survey) to the corresponding 1975 distribution of births by age of mother and parity;
- the rate T_{50} observed in 1950 (20.0 per 1,000) and the standardized rate T'_{75} (18.8 per 1,000) were compared, revealing a more favourable structure in 1975;
- the contribution of distributional changes (age of mother/parity) in the decline in rates between, 1950 and 1975 was calculated as:
  $(T_{50} - T'_{75})/(T_{50} - T_{75}) = (20.0 - 18.8)/(20.0 - 11.6) = 0.14$, or 14% ($T_{75}$ being the rate **observed** in 1975).

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34 This is in fact a standardization that is equivalent, in principle, to that which led to the standardized death rate (see I-02), using the standard-population method. Here, the standard-rate method has been used, with rates t'_x for 1950 being taken as the standard. For 1950, then, $t_x = t'_x$ and T = T'.

35 Williams, R. and Chen, P., "Identifying the sources of the recent decline in perinatal mortality rates in California", **New England Journal of Medicine**, Vol. 306, 4, January 28, 1982, p. 211.

36 Usher, R., "Changing mortality rates with perinatal intensive care and regionalization", **Seminars in Perinatalogy**, Vol. 1, 3, July 1977, p. 310.

37 Lee, K.-S., **et al.**, "Neonatal Mortality: An Analysis...", **op. cit.**, p. 19.

TABLE 83. Early Neonatal Mortality Rate by Age of Mother and Selected Characteristics, 1971 Birth Cohort, Canada[1]

	Age of mother at childbirth						
	All ages	Less than 20 years	20-24 years	25-29 years	30-34 years	35-39 years	40 years and over
	per 1,000 total births						
Total	**7.1**	**8.8**	**7.2**	**6.5**	**6.6**	**7.2**	**10.0**
(N)[2]	(347,885)	(40,240)	(123,796)	(108,391)	(48,573)	(20,281)	(6,076)
Birthweight and total birth order[3]							
≥ 2 500 g	2.2	1.9	2.1	2.2	2.3	2.8	4.1
< 2 500 g	70.7	82.0	73.7	67.3	63.8	58.7	74.2
< 2 500 g and birth order 1	65.6	69.1	61.2	68.8	65.7	80.2	87.0[4]
" " 2	72.7	100.4	79.7	62.1	60.8	48.6	85.1[4]
" " 3	72.3	218.5	89.7	59.6	56.9	47.8	36.4[4]
" " 4 and over	78.0	437.5[4]	114.2	82.2	68.3	60.0	76.9
Mother's marital status							
Married	6.9	7.9	7.0	6.4	6.4	6.9	10.3
Not married	9.8	10.6	9.3	7.4	12.6	14.0	4.3[4]

1 Excluding Newfoundland.
2 Total number of live births 1 000 g and over.
3 i.e. including stillbirths.
4 Less than 10 deaths.
Source: Statistics Canada, Health Division, unpublished data.

It should be recalled that, for perinatal mortality in general, this distributional factor played a significant role in Quebec, since it was responsible for 34% of the decrease between 1965 and 1974.[38] In the case of Quebec, the magnitude of the distributional factor may be explained by the fact that the period studied coincided with a drop in fertility which, by its speed and magnitude, was possibly without equal in the history of populations, and has brought about major changes in the intensity and tempo of fertility.

The Indicator

The early neonatal mortality rate provides a **valid** indicator of the level of perinatal care, during the first week of life in particular. The decline in this rate coincided with major advances in this area and, in addition, centres with intensive care units showed much lower rates than the rest of the country, which also gives a good idea of progress that may yet be made, given the present state of knowledge. These results, in addition to the fact that the decline in the rate accelerated with the introduction of intensive care, show that the indicator is **sensitive**. It is also **specific**, insofar as almost all changes are due to perinatal care.[39] The indicator may also be described as **reliable**, since good accessibility of neonatal care generally corresponds to very low rates. Standardized rates must, however, be used in comparisons, while bearing in mind that changes in the indicator may be caused by other factors than the level of care or structural factors. The city of New York provides a striking example of this: more liberal abortion laws had brought about a sharp drop in the proportion of births under 1 000 g after 1971, with the result that the neonatal mortality rate declined considerably.[40]

38 Bernard, J.-M., **Analyse de la mortalité infantile et périnatale au Québec, 1965-1974**, Ministère des Affaires sociales, Government of Quebec, September 1978, p. 27.

39 The Quebec perinatal program not only involved the installation of intensive care units for the newborn, but also, for high-risk women, a policy of transportation and of transfer among hospitals. In addition both mothers and newborns benefited from a policy of regionalization of the health care system.

40 Lee, K.-S., et al, "Neonatal Mortality: An Analysis ...", **op. cit.**, p. 19.

III TECHNICAL DISCUSSION

Sources and Calculations

The early neonatal mortality rate is obtained by dividing the number of deaths among live-born children aged less than one week by the total number of live births during that year. For 1981 in Canada, this would give: (2,037/371,346) x 1,000, or an early neonatal mortality rate equal to 5.5 per 1,000 live births.

For international comparisons, W.H.O. recommends using only births where weight was equal to or greater than 1 000 g. This value is based on viability criteria, but is also aimed at attenuating the effects of variations in data, since certain countries include all infants showing any sign of life, while others have imposed another criterion, for example minimum birthweight.

As has been seen, the level of the early neonatal mortality rate is closely linked to certain characteristics at birth (age of mother, parity, weight, etc.). When this information is available, it is shown on the birth certificate and cannot be easily related to data shown on death certificates except through data linkage. Such a linkage was carried out in Canada between the certificates of live births for 1971 and infant deaths occurring for that cohort in 1971 and 1972. A second linkage is now being carried out for the 1978 live births.

Qualities of the Indicator

Since it is presented in the form of a risk, or probability of dying, the early neonatal mortality rate is **intelligible**. The data entering into the calculation are normally available and, in Canada for example, the degree of quality and uniformity is all the higher since almost all births (and early neonatal deaths) take place in hospital.

In spite of the existence of precise definitions at a national level, however, a certain degree of subjectivity persists, particularly in borderline cases. The following two examples are taken from the literature:

- Lee, **et al.**,[41] mention the case of Georgia (United States) where, on investigation, it was discovered that between 1974 and 1977, 21% of neonatal deaths (0-27 days) had not been reported and that this error involved mainly infants of very low weight. If newborns at the limit of viability have a better chance of being registered as live births than as stillbirths, but their death is not reported, this has the effect of underestimating the level of mortality, in particular for very-low-weight babies. It would accordingly be useful to determine whether this is only an isolated case of non-reporting;
- similarly, a W.H.O. study mentions the problem of "live-born but not viable" infants who are sometimes reported as live-born, and sometimes as stillborn.[42]

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41 "Neonatal Mortality: An Analysis ...", **op. cit.**, pp. 19-20.
42 W.H.O., "Comparative study of social and biological effects on perinatal mortality", **World Health Statistics Report**, Vol. 29, 4, 1976, p. 229.

I-19: INCIDENCE OF LOW BIRTHWEIGHT

I DESCRIPTION

Definition

Percentage of live-born infants whose birthweight is judged to be insufficient, i.e. less than 2 500 g (see technical discussion).

Descriptive Function

Considered more objective and easier to obtain than length of gestation,[43] birthweight gives an idea of the stage of development reached by the fetus and/or its rate of growth. Low birthweight is associated with prematurity or slow growth of the fetus, or with a combination of these two factors. When the data available permit, it is recommended to isolate among low-weight births those occurring at a gestational age equal to or greater than 37 weeks (i.e. infants born at full-term, but "small-for-dates"), and place the others in the premature category.

Indication Sought

Low birthweight, which generally results from conditions having an unfavourable effect on the mother's health, is "the most significant indicator of the risk to the survival of a baby and its healthy growth and development and is thus an important guide to the level of care needed by individual babies".[44, 45]

The incidence of low-weight births provides an important indicator of the health level of the population, but also of its social development, since the frequency of low birthweight is very sensitive to socio-economic conditions.

II INTERPRETATION

Although it does not constitute a direct measurement of health status, low birthweight is a qualitative demographic indicator that is simple to obtain and very informative. The incidence of low-weight births in a population is closely linked to the frequency of appearance in women of characteristics which must be recognized in order to properly design preventive programs. For newborns, low weight is often associated with precarious health, manifested by higher than average morbidity and mortality.

Risk Factors and Risk Markers

The overall health status of the pregnant mother determines, to a certain extent, that of the unborn child. It is, however, becoming increasingly apparent that the baby's health, and particularly its birthweight, also depend on the mother's behaviour during pregnancy.[46]

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43 This duration does not necessarily measure the degree of fetal development and therefore does not constitute a sufficiently precise indicator of maturity.

44 W.H.O., **Development of Indicators for Monitoring Progress towards Health for All by the Year 2000** ("Health for All" Series, No. 4), W.H.O., Geneva, 1981, p. 64.

45 See also Lee, K.-S., **et al.**,"The very low-birth-rate: Principal predictor of neonatal mortality in industrialized populations", **The Journal of Pediatrics**, 97, 5, November 1980, pp. 759-764.

46 W.H.O., "The Incidence of Low Birth Weight: A Critical Review of Available Information", **World Health Statistics Quarterly**, Vol. 33, 3, 1980, pp. 197-224.

Smoking is notorious in this regard. It ranks among the main risk factors, and its role in the incidence of low birthweight, demonstrated as early as 1957, has since been confirmed many times.[47] The data collected by Meyer, **et al.**, are eloquent (Table 84): the risk of having a low-birthweight baby are twice as high among women who smoke during pregnancy as among non-smokers and, in the studies quoted, 21 to 39% of low-weight births might be attributed to the use of tobacco. Fabia has also shown that the risk increases with the number of cigarettes smoked per day.

TABLE 84. Cigarette Use during Pregnancy and Low-weight Births: Data from some Published Studies

Study	Number of mothers	Percentage of smokers	Percentage of births under 2 500 g		Relative risk	Attributable risk[1] (percentage)
			Non-smokers	Smokers		
	(1)	(2)	(3)	(4)	(5) = (4)/(3)	(6)
Cardiff	13,414	46.5	4.1	8.1	1.98	31
U.S. Collaborative:						
white population	18,247	53.6	4.3	9.5	2.21	39
black population	19,029	40.9	10.7	17.5	1.64	21
California, Kaiser Permanent:						
white population	5,334	40.2	3.5	6.4	1.83	25
black population	1,413	33.8	6.4	13.4	2.09	27
Province of Quebec	6,958	43.2	5.2	11.4	2.19	34
Province of Ontario	48,378	43.5	4.5	9.1	2.02	31

1 Percentage of all births of weight under 2 500 g attributable to mother's smoking.
Source: From Table 1 in Meyer M., Jonas B. and Tonascia J., "Perinatal Events associated with Maternal Smoking during Pregnancy", **American Journal of Epidemiology,** Vol. 103, 5, 1976, pp. 464-476.

Apart from smoking, alcohol consumption and eating habits, little is known about the risk factors that favour low birthweight. In the case of malnutrition, for example, one study claims that it is at the origin of around a third of births under 2 500 g.[48] To our knowledge, however, there has been no measurement of the effects of medical surveillance during pregnancy on the prevalence of low birthweight, but it may reasonably be assumed that these are favourable, if only through the information on risk factors thus made available. It might be noted in this connection that the success of perinatal programs militates in favour of medical surveillance.

47 See, in this connection, Fabia, J., "Cigarettes durant la grossesse, poids de naissance et mortalité périnatale", **Canadian Medical Association Journal**, Vol. 109, December 1, 1973, pp. 1104-1109, and United States. U.S. Department of Health, Education and Welfare, **The Health Consequences of Smoking for Women**, A Report of the Surgeon General, Washington, D.C., U.S. Government Printing Office, 1980, pp. 191-194.

48 Quoted in United States. **Health Status of Minorities and Low-Income Groups**, U.S. Department of Health, Education and Welfare, Washington, D.C., 1979, p. 62.

Aside from the risk factors just mentioned, another category of characteristics, which may be classified as risk markers, will aid in detecting those women who are particularly exposed. Among these are length of gestation, parity, birth spacing, age of mother, marital status, education and occupational class (Table 85).

TABLE 85. Distribution of Births by Weight, for Selected Occupational Classes, United Kingdom, 1970

Birthweight	Occupational class[1] (mother's husband)			
	I and II	III	IV and V	Unknown[2]
	percentage			
Less than 2 500 g	4.5	5.6	8.2	9.5
More than 3 000 g	81.0	76.3	72.7	66.7
All categories	**100.0**	**100.0**	**100.0**	**100.0**

1 Occupational classes: I (Professionals); II (Intermediate); III (Skilled workers); IV (Partly skilled workers); V (Unskilled workers).
2 Divorced, widowed, separated and single women.
Source: Table 2.4 in Black, D., **Inequalities in Health.** Report of a Research Working Group, **op. cit.**, p. 29.

Table 86, for example, shows the role of mother's age and parity. For each of these variables, the low birthweight incidence curve has a U-shape, i.e. the highest values are generally at the extremities of the distribution: mothers at either end of the reproductive age range; first births and parities of order four or higher. Marital status also plays a significant role: among births to unmarried mothers (11% of the total in 1980), there is a higher proportion of low-weight newborns, and this is mainly due to the often unfavourable conditions during pregnancy.

Using Table 86 and the results of other studies, one may list certain of the population categories where the risk of giving birth to a low-weight child is particularly high: mothers at either end of the reproductive age range, smokers, disadvantaged groups either by way of income or education, etc.

It is important to note that these characteristics are not independent. Higher ages of mothers are often associated with shorter birth intervals, while low education levels often coincide with higher than average fertility and low income. It is also known that different social groups do not have the same attitude towards medical care, the poorer groups having an attitude that favours cure rather than prevention, and it may reasonably be assumed that these groups would be less likely to seek medical supervision during pregnancy. The Canada Health Survey showed, in addition, that the proportion of smokers was clearly higher among the more disadvantaged groups.

Low Birthweight, Excess Morbidity and Excess Mortality

Low birthweight i.e., weight lower than 2 500 g at birth, makes newborns more susceptible to perinatal morbidity in general and more particularly to neurological conditions which become more frequent as birthweight decreases. A Scottish study showed that low birthweight quadruples the risk of all forms of handicap at age 5.[49]

49 Quoted by Blanchet, M., and Levasseur, M., "Périnatalité: bilan et prospective", **Carrefour des affaires sociales,** Vol. 2, Special Edition, September 1980, p. 13. See also W.H.O., "The Incidence of Low Birth Weight..", **op. cit.**, p. 198.

TABLE 86. Incidence of Low Birthweight by Age of Mother and Selected Characteristics, 1971 Birth Cohort, Canada[1]

	Age of mother at childbirth						
	All ages	Less than 20 years	20-24 years	25-29 years	30-34 years	35-39 years	40 years and over
	percentage						
Total	**7.5**	**9.2**	**7.5**	**6.9**	**7.3**	**8.3**	**8.8**
(N)[2]	(349,256)	(40,453)	(124,263)	(108,785)	(48,763)	(20,362)	(6,100)
Total birth order[3]							
1st	7.7	8.5	7.2	7.2	9.4	11.5	12.4
2nd	7.0	12.0	6.9	6.1	6.7	8.9	9.0
3rd	7.3	16.8	9.0	6.7	6.0	7.2	7.8
4th and over	8.4	21.3	11.1	8.6	7.7	8.0	8.6
Marital status of mother							
Married	7.2	8.6	7.2	6.8	7.1	8.0	8.6
Not married	10.8	10.4	10.4	11.2	12.5	14.4	12.7
Length of gestation (weeks)							
Less than 37	42.5	54.2	42.8	39.4	39.3	39.8	41.0
37 and over	4.3	4.6	4.3	4.1	4.2	4.9	4.8

1 Excluding Newfoundland.
2 Number of live births.
3 i.e., calculated taking into account stillbirths and live births.
Source: Statistics Canada, Health Division, unpublished data.

Along with the excess morbidity experienced by low-birthweight babies, there is a certain degree of excess mortality, particularly during the first year of life. An example from Canadian data will give an idea of the extent of this excess mortality according to certain characteristics observed at birth: it was noted that, during the first week and first year of life, low-birthweight infants experienced much higher mortality than others: 32 times higher in the case of early neonatal mortality (Table 83 in I-18), and 18 times higher for infant mortality (Table 73 in I-16). Among low-birthweight newborns, the risk of dying is particularly high when the mother is at either end of the reproductive age range, and birth order also appears to be a risk factor.

Some Qualities of the Indicator

Due to the simplicity of its calculation and the concrete significance of the result obtained, low birthweight is one of the most intelligible health indicators.

Since it is closely linked to the health of the future mother on the one hand, and to the present and future health of the newborn child and its chances of survival on the other, this is a valuable indicator of the health of the population. For example, newborns weighing less than 500 g are not considered viable; from 501 to 1 000 g, they are at the limit of viability and are faced with certain very specific health problems, which explains the special treatment they often receive in statistical studies. Weight of less than 2 500 g, although a somewhat arbitrary criterion, allows premature babies to be identified.[50]

50 See Usher, R., "Changing mortality rates with perinatal intensive care and regionalization", **Seminars in Perinatalogy**, Vol. 1, 3, July 1977, pp. 309 and 317-319.

A reduction in the incidence of low birthweight is one of the signs of an improvement in health conditions for both mother and child, which explains the fact that this is one of the goals of perinatal programs.[51] In a preventive perspective, that is, aimed at preventing low-weight births, promoting a healthy lifestyle for teen-age girls and pregnant women remains a major objective, since the birth of low-weight infants is, and will always be, more problematic than that of normal weight babies, no matter how much progress is made in the area of neonatal care.

The indicator accordingly varies with health status, and also with the quality and quantity of care available. As has just been seen, however, these changes are not always in the expected direction. Progress in perinatal care is an example: the ensuing reduction in the number of miscarriages and stillbirths has in fact increased the probability of low-weight births.

The incidence of low birthweight should therefore be used with caution in comparisons between periods or areas. For example, a higher percentage of low-weight births was noted in Great Britain than in neighbouring countries. This is apparently due to frequency of induced labour, which raises the incidence of low birthweight by increasing the proportion of babies who are "small-for-dates" among low-birthweight babies.[52] Differences between countries, or between periods, may also be explained by very different distributions of births by various characteristics such as birth order, age of mother, etc.

III TECHNICAL DISCUSSION

Besides being simple to calculate, the incidence of low birthweight is also based on very reliable data: under-registration of births is negligible and, since in Canada almost all births (98% in 1980) take place in hospitals, birthweight is recorded under uniform conditions by qualified personnel, thus making this a measurement that is both stable and representative of the target population.

In 1982, there were 363,380 live births of known birthweight in Canada (excluding Newfoundland), of which 21,263 weighed 2 500 g or less, giving an incidence of low birthweight equal to 5.8% (see Table 87). In spite of the simplicity of this calculation, it should be remembered that some precautions may facilitate the use of the indicator, especially for comparisons over time and space.

Since 1948, the definition of low birthweight has been based on an international definition of prematurity, i.e. a weight equal to or less than 2 500 g. Starting in 1976, however, it has been recommended to include only newborns weighing less than 2 500 g (i.e. 2 499 g or less). Although most published studies are still based on the old definition, the existence of the two definitions should be borne in mind since, given a certain attraction for round figures, it appears that the indicator obtained may vary significantly depending on the definition chosen.[53]

It should also be pointed out that, since births of less than 500 g are not considered viable, studies such as that of Dr. Usher exclude them. In point of fact, the trend now is increasingly towards considering newborns weighing 1 000 g and less as viable. In former times, these births were not always registered or were counted as stillbirths, but this is no longer the case. It might be advisable, in the future, to envisage calculating the various rates (stillbirth, early neonatal mortality, perinatal mortality) on the basis of a scale of different weights, e.g.: 500-749 g, 750-999 g, 1 000-1 499 g, 1 500-1 999 g, etc.

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51 For Quebec, for example, see Blanchet, M., and Levasseur, M., **op. cit.**

52 W.H.O., "The Incidence of Low Birth Weight...", **op. cit.**, p. 203.

53 W.H.O., "The Incidence of Low Birth Weight...", **op. cit.**, p. 199. See also: Mcfarlane, A. and Mugford, M., **Birth Counts. Statistics of Pregnancy and Childbirth**, London, H.M.S.O., 1984, pp. 6-7, and Table 2.5.

TABLE 87. Incidence of Low Birthweight (2 500 g or less) by Age of Mother, Canada, 1965-1982

Year	Age at childbirth						
	All ages	Less than 20 years	20-24 years	25-29 years	30-34 years	35-39 years	40 years and over
	percentage						
1965	7.6	9.2	7.6	6.8	7.1	8.0	8.5
1966	7.8	9.3	7.7	7.1	7.6	8.3	8.6
1967	7.9	9.8	7.8	7.0	7.6	8.5	8.6
1968	7.7	9.1	7.7	7.1	7.5	8.2	8.8
1969	7.8	9.8	7.6	6.9	7.4	8.8	9.0
1970	7.9	9.7	7.8	7.1	7.6	8.3	8.5
1971	7.5	9.2	7.5	6.9	7.3	8.3	8.8
1972	7.3	9.1	7.2	6.6	7.1	8.0	8.9
1973	7.0	8.7	6.9	6.2	7.0	7.9	8.1
1974	6.9	8.5	6.9	6.3	6.8	8.2	8.7
1975	6.8	8.3	6.9	6.1	6.4	7.6	8.1
1976	6.6	8.1	6.7	6.0	6.3	7.4	9.0
1977	6.4	8.0	6.6	5.8	6.0	7.5	8.6
1978	6.3	7.9	6.6	5.8	5.7	7.0	8.0
1979	6.1	8.0	6.4	5.6	5.5	6.4	8.0
1980	6.0	7.6	6.4	5.5	5.5	6.8	8.2
1981	6.0	7.9	6.4	5.5	5.4	6.9	8.4
1982	5.8	7.7	6.2	5.3	5.3	6.2	8.2

Source: Adapted from D.B.S., **Vital Statistics**, Catalogue 84-202 (1965 to 1970) and Statistics Canada, **Vital Statistics**, Vol. I, Births, Catalogue 84-204 (1971 to 1982).

The appropriateness of classifying low-weight newborns by length of gestation, as illustrated by Table 88, has already been emphasized in the description of this indicator. Over half the babies born with low birthweight in 1982 were premature (less than 37 weeks of gestation) and, among these, the incidence of low birthweight was 20 times higher than for other lengths of gestation.

TABLE 88. Distribution of Low-weight Births and Incidence of Low Birthweight, by Length of Gestation, Canada,[1] 1982

Length of gestation (in weeks)	Births of 2 500 g or less		Low-birthweight incidence (percentage)
	Number	Percentage	
37 and over	9,363	44.2	2.7
Less than 37	11,823	55.8	54.5
Total	**21,186**	**100.0**	**5.8**

[1] Excluding Newfoundland.

Source: Adapted from Statistics Canada, **Vital Statistics 1982**, (Vol. I: Births and Deaths), Catalogue 84-204, Table 14, pp. 22-23.

I-20: LIFE EXPECTANCY BY MARITAL STATUS

I DESCRIPTION

Definition

For a sub-population of a given marital status, this is the mean duration of life assuming that the mortality specific to that sub-population remains stable at the level observed at various ages during a year or a given period.

Descriptive Function

Mortality conditions particular to a given marital status as observed during a year or other period are attributed to a synthetic cohort. By doing this, the fate of a group of individuals is reproduced under the following conditions: at the start of observation, for example at their 30th birthday, they all have the same marital status; this marital status may not change over time, and the initial size of the cohort may only be reduced through mortality, the level of which is specific to the marital status considered.

This simulation is repeated for each sex and each marital status and leads to eight series of results, summarized as mean lengths of life, or life expectancies. These depend only on the mortality conditions specified and accordingly constitute eloquent and specific descriptors of mortality by marital status.

Indication Sought

This would be an indication of the level of intrinsic mean health for various categories of the population distinguished by their marital status, the implicit assumption being that there is a positive relationship between life expectancy and level of health.

II INTERPRETATION

The interest aroused by differences in mortality according to marital status is not new. In the 19th century, Bertillon had observed and suggested explanations for excess mortality among never-married persons in France.

Life Expectancy by Marital Status in Canada

Statistics Canada recently proposed, for the first time, life tables by marital status,[54] the results of which are compatible with published life tables for the corresponding period, i.e. 1975-77.

Part of these results are shown in Table 89 which summarizes, in the form of life expectancies, the levels of mortality for two periods of life: beyond age 30 and beyond age 65. One may then say that, given the mortality conditions prevailing in 1975-77, men still alive at age 30 might expect to survive an average of 42.9 years, although this life expectancy could vary considerably, from 34.7 years for divorced men to 44.3 years for married men.

Taken as a whole, the results identify two sub-populations: married persons and non married persons, the former being at an advantage from a mortality point of view (Table 89). For each sex, one finds the same ranking of categories, however, for women the spread between the highest and lowest categories (married and divorced) is much smaller: 4.6 years compared to 9.6 years for men.

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54 Adams, O.B. and Nagnur, D.N., **Marriage, Divorce and Mortality: a Life Table Analysis for Canada, 1975-1977**, Catalogue 84-536, Statistics Canada, Ottawa, May 1981, 91 p.

TABLE 89. Life Expectancy at Age 30 and at Age 65, by Sex and by Marital Status, Canada, 1975-77

Marital status	Sex and exact age				Difference between sexes	
	Males		Females			
	Age 30	Age 65	Age 30	Age 65	Age 30	Age 65
			years			
Total	**42.9**	**14.0**	**49.6**	**18.4**	**6.7**	**4.4**
Single	37.4	12.5	47.9	18.5	10.5	6.0
Married	44.3	14.8	50.5	19.0	6.2	4.2
Widowed	36.4	12.5	47.3	18.2	10.9	5.7
Divorced	34.7	11.3	45.9	16.5	11.2	5.2

Source: From Tables 9 to 18 in Adams, O.B. and Nagnur, D.N., **op. cit.**, pp. 42-51.

In each marital status category, men usually experience a certain degree of excess mortality, and this is particularly high among men not currently married. The most disadvantaged group of women, divorcees, nevertheless display mortality lower than that of married men, who enjoy the longest average life duration in males.

Time trends in the excess mortality of the never-married appear to indicate that the differences in mortality by marital status noted above have tended to become more pronounced (Table 90). This might be due to an increase in the intensity of the selectivity phenomenon, nuptiality in this case: the greater the intensity of nuptiality, the larger the proportion of "hard to marry" persons among those remaining unmarried.[55]

Marriage: Does it Select for Health or Protect Health?

This question, the sub-title of an article[56] dealing with this subject, neatly sums up the main concerns of researchers in this field.

It has been noted that variations of life expectancies by marital status may be quite large. Unfortunately, available data do not enable their explanation, although Vallin and Nizard suggest four plausible hypotheses:

- a factor specific to marital status: the fact of living alone or not, particularly in view of the lifestyle this implies, effectively distinguishes married persons from other categories; this is the **protective role of marriage**;
- a factor linked to **change of status**: this change may bring about a shock, positive in the case of marriage and negative in the case of widowhood, and either positive or negative depending on circumstances in the case of divorce;
- a **selection** factor: all individuals are initially unmarried. Moving from an unmarried to a married state then, in certain cases, to divorce or widowhood, occurs according to certain rules which often amount to a form of selection; this is more or less rigorous depending on the circumstances. Some of the criteria involved have to do with health. For example, those in poorer health may have more difficulty getting married and are therefore found in greater proportions among those who remain unmarried. A selection factor also acts against the widowed. All other things being equal, widowhood is obviously more frequent

[55] See Vallin, J. and Nizard, A., "La mortalité par état matrimonial. Mariage sélection ou mariage protection?", **Population**, Special Issue, September 1977, p. 98.
[56] The contents of this section are, in the main, drawn from Vallin, J. and Nizard, A., **op. cit.**, pp. 95-119.

TABLE 90. Excess Mortality Index[1] for Never-married Persons by Sex, for Selected Age Groups, Canada, 1960-1982

Years	Males			Females		
	15-24 years	25-44 years	45-64 years	15-24 years	25-44 years	45-64 years
1960	127	180	150	107	160	134
1965	136	191	155	132	167	137
1970	155	202	169	138	187	140
1975	179	248	191	176	209	152
1980	208	272	207	235	232	162
1982	242	270	213	272	222	165

1 Ratio of the never-married death rate to that of married persons, expressed in percentage.

Source: Dumas, J., **Mortality in Canada. A Perspective for the 1980s** ("Current Demographic Analysis" Series), Statistics Canada, Ottawa, forthcoming, and for 1980 and 1982: Statistics Canada, Deaths by Marital Status, Age and Sex, unpublished data; Statistics Canada, **Estimations of population by marital status, age and sex**, Catalogues 91-519 and 91-203.

in high-mortality groups and, since the surviving spouse is generally subject to the same living conditions, the widowed would be exposed to higher risks of dying than the average for the population;

- a factor due to **errors of observation**: errors may occur in the collection of vital statistics data, for mortality, and in census-taking, for total population. Statements as to marital status are not strictly verified, and this may lead to errors which, in certain cases, may be systematic and which have a particularly great impact on smaller population groups such as those widowed at early ages.

Vallin and Nizard (**op. cit.**, p. 117) conclude that the three factors involved (selection, protective role of marriage and change of status) indeed exist, and this is confirmed by their study of causes of death. But the roles of these factors, according to them, remain vague and hard to dissociate, let alone measure.

Marital Status and Health

Whatever may be the significance of a possible link between marital status and health level, observation at least seems to confirm the existence of an association between the two: to a given marital status corresponds a life expectancy, and it is agreed that life expectancy is an indicator which is positively linked to health level.

Let us take an example, that of the widowed, for whom a change in marital status may have brought about an alteration, if only temporary in health status, according to the results of certain studies. Durkheim had already observed, in the case of suicide, the excess mortality of the widowed. Later, Young, **et al.**,[57] pointed out a striking fact: that of the particularly high excess mortality of widowers during the six months following the death of their spouse. A number of explanations were proposed for this phenomenon, including one dealing with biological changes in the surviving spouse. Quite recently, this hypothesis has become more believable, since reduced immunity following the death of a spouse might well explain excess morbidity and mortality among the widowed.[58]

57 Young, M., **et al.**, "The Mortality of Widowers", in Ford, T.R. and de Jong, G.F. (Eds.), **Social Demography**, Englewood Cliffs, Prentice-Hall, 1970, pp. 172-177.

58 Schleifer, S.J., **et al.**, "Suppression of Lymphocyte Stimulation Following Bereavement", **Journal of the American Medical Association**, Vol. 250, 3, July 15, 1983, pp. 374-377.

In addition, widowhood may occasionally be caused by an event which has a direct effect on the health of both spouses. In the case of fatal traffic accidents, for example, which affect young couples to a greater extent, excess mortality among surviving spouses may be explained by the sequelae of these accidents.

Finally, if the existence of a "shock" following the loss of a spouse is accepted, the method of calculating life expectancy (see technical discussion) leads to an overestimation of mortality in the widowed population. In this method, risks of death at various ages, obtained from cross-sectional data, are then attributed to a synthetic cohort for which life expectancy is calculated. This average duration of life is aimed at summarizing the mortality conditions experienced by the average individual after a certain age. However, due to the simulation that is used, this individual in fact experiences the shock of the death of a spouse several times over the life cycle, and the result is an underestimation of e_x.

The Indicator

The proposed indicator is convenient since it summarizes, in a single number, the conditions specific to a sub-population identified by marital status. Its limits are, however, precisely due to the relatively simple method by which it is calculated (see technical discussion). In particular:

- the use of a "cross-sectional" table - which is only an artifact of calculation - which may only be interpreted in a longitudinal perspective under certain hypotheses;
- the definition of categories. On the one hand, it is hypothesized that the sub-populations involved are homogeneous and thus that marital status is given once and for all. No account is taken of the marital history of individuals: changes from one state to another throughout their lifetimes, length of time spent in each state. On the other hand, the selected state is that at the time of death, i.e. at an age that varies from one individual to another.

III TECHNICAL DISCUSSION

Sources of Data

Two series of data are required: those concerning the events studied, i.e. deaths, and those dealing with the population exposed to the risk of experiencing these events.

The first series, deaths by marital status, is compiled by age for each calendar year and drawn from **vital statistics** data. The second series is obtained from **census** data, that is, every five years, with the last compilation going back to June 3, 1981. Statistics Canada also produces **estimates** for June 1st of each of the intercensal years.[59] It is preferable to calculate tables by marital status for periods centred on a census year, since population statistics are more accurate. In addition, these periods correspond to those chosen for Statistics Canada's published life tables.

It should, however, be noted that vital statistics involve **de jure** marital status, while the census questionnaire deals with **de facto** status. This distinction is important, since it results in death rates which are overestimated for the never-married.

Life Table by Marital Status

This is a gross, single-decrement table that is obtained using the same principle as for the "period life table" (see the technical discussion of I-03). In this case, however, the calculation is made separately for each marital status. There are three main steps:

[59] Two types of estimates are produced: **postcensal** and **intercensal**. The latter are compatible with census results and are published after each census in Catalogue 91-519, Occasional, except for the years prior to 1971, when estimates appear in Catalogue 91-203.

- **calculation of death rates.** For a given marital status, the ratio is calculated between deaths D_x at each age x and the corresponding population P_x:

$$t_x = D_x/P_x$$

- **transformation of rates t_x into probabilities q_x**, using the relationship:

$$q_x = 2t_x/(2+t_x) \quad \text{or} \quad {}_5q_x = 10\,{}_5t_x/(2+5\,{}_5t_x) \text{ when using five-year age groups.}$$

- **calculation of life table survivors S_x.** Risks of death q_x are applied to a synthetic cohort whose initial size, the radix of the table, is 100,000 individuals. In the example presented, the calculation begins at age 30; this choice is somewhat arbitrary, but is justified mainly by the fact that, prior to that age, the phenomena studied do not occur frequently enough to allow the rate to be calculated (this is mainly true for the widowed and divorced). The following series is obtained (Table 91), using five-year age groups:

If $S_{30} = 100{,}000$

then:

$$S_{30} \cdot {}_5q_{30} = d(30,35)$$

with d representing life table deaths. And:

$$S_{30} - d\,(30,35) = S_{35}$$

this calculation is repeated for the subsequent age groups:

$$S_{35} \cdot {}_5q_{35} = d(35,40)$$

$$S_{35} - d(35,40) = S_{40}$$

etc.

Thus step by step, Column 2 of Table 91 is obtained that is, the survivors at various birthdays x.

Calculating Life Expectancy

Knowledge of the series of survivors now enables the calculation of the number of years lived in each age interval, and then life expectancy. For details of this calculation, the reader should refer to the paragraph entitled "Years lived and life expectancy" in the technical discussion of I-03.

In the case of stationary populations - in this case that associated with the life table - the death rate is equal to the inverse of life expectancy at birth. Life expectancy after age 85 is then obtained using the relation:

$$e_{85} = 1/t_{85+}$$

where t_{85+} is the death rate of the 85 and over age group for the marital status in question.

TABLE 91. Construction of a Life Table for Never-married Males, Canada, 1975-77

Birthday x	$_5q_x$	S_x	d(x,x+a)	Years lived A_x	Cumulative years lived T_x	e_x
	(1)	(2)	(3)	(4)	(5)	(6)
30	0.01934	100,000	1,934	495,165.0	3,734,196.5	37.3
35	0.02865	98,066	2,810	483,305.0	3,239,031.5	33.0
40	0.04179	95,256	3,981	466,327.5	2,755,726.5	28.9
45	0.05892	91,275	5,378	442,930.0	2,289,399.0	25.1
50	0.05892	85,897	7,088	411,765.0	1,846,469.0	21.5
55	0.11694	78,809	9,216	371,005.0	1,434,704.0	18.2
60	0.14934	69,593	10,393	321,982.5	1,063,699.0	15.3
65	0.21133	59,200	12,511	264,722.5	741,716.5	12.5
70	0.27857	46,689	13,006	200,930.0	476,994.0	10.2
75	0.37609	33,683	12,668	136,745.0	276,064.0	8.2
80	0.50545	21,015	10,622	78,520.0	139,319.0	6.6
85		10,393	10,393	60,799.0	60,799.0	5.9

Source: Adapted from Table 10 in Adams, O.B. and Nagnur, D.N., **op. cit.**, p. 43.

I-21: EXCESS MALE MORTALITY INDEX

I DESCRIPTION

Definition

Ratio of the male death rate (or death probability) to the female death rate (or death probability).

Descriptive Function

The excess male mortality index measures male mortality, with female mortality being taken as the unit of comparison. It is usually calculated using death rates (or probabilities), and the result is most often expressed as an index, with female mortality as the base (i.e. equal to 100).

Indication Sought

Insofar as death rates give an indication of the level of actual mean health of the population, the excess male mortality index shows the extent of sex differentials in this regard by age or for various categories of the population. If it is accepted that a good part of excess male mortality is attributable to differences in lifestyle, the mortality differences observed give an idea of possible progress and enable preventive measures, for example, to be better directed.

II INTERPRETATION

Although in certain populations excess female mortality still exists, being basically linked to maternal mortality, excess male mortality at all ages is now almost universal and constitutes one of the best-known inequalities in the area of mortality.

Trends in Excess Male Mortality[60]

Table 92 traces excess male mortality over the past 50 years for broad age intervals. Except for the first year of life, when the index is remarkably constant, it may be seen that the gap has widened where excess male mortality already existed and that, for the 15-35 age interval, where there was excess female mortality in 1931, male risks are now close to three times higher than female risks.

The transition from a state of low excess mortality to a state of high excess mortality is clearly shown by the elongated S-shape of the curves in Figure 21. This movement is accompanied by an upset in the ranking of indices, symmetrical to that which prevailed at the beginning of the period considered. It may be seen that the main part of this transition occurred during the 1940s and 1950s, that is, it is contemporaneous with the acceleration in the decline of mortality after the introduction of antibiotics.

An overall measure of excess male mortality is given by the gap between male and female life expectancies. Table 93 appears to show a correlation between an improvement in life expectancy at birth and the widening of this gap, a phenomenon found in many low-mortality countries.[61, 62]

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60 The following is patterned after an analysis of the Quebec situation by Dufour, D. and Péron, Y., **Vingt ans de mortalité au Québec. Les causes de décès, 1951-1971** ("Démographie canadienne" Series, No. 4), Montréal, Presses de l'Université de Montréal, 1979, pp. 58-59.

61 See, for example, the chronological series annexed to the article by Aubenque, M. and Damiani, P., "Espérance de vie à la naissance: différences suivant le sexe, évolution, limites", **Santé Sécurité Sociale, Statistique et commentaires**, No. 1, January-February 1982, pp. 17-40.

62 Note that it is possible to estimate the contribution of each age to the difference between men and women in total life expectancy (Figure 22). See the method suggested by Pressat, R., in "Perspectives de réduction de la surmortalité masculine dans les pays ayant une faible mortalité", **Meeting on sex differentials in mortality: trends, determinants and consequences**, Canberra, The Australian National University, December 1-7, 1981. Quoted in Vallin, J., "Tendances récentes de la mortalité française", **Population**, 38, 1, January-February 1983, p. 98 (The latter article gives examples of such results).

TABLE 92. Excess Male Mortality Index,[1] Canada, 1931-1981

Year	Age interval				
	0-1 year	1-15 years	15-35 years	35-60 years	60-85 years
1931	125.5	112.6	94.1	107.2	103.6
1941	126.7	122.1	113.0	121.6	106.8
1951	126.4	132.4	161.0	146.1	109.7
1956	125.5	137.3	209.2	159.9	113.2
1961	128.1	144.3	221.2	173.2	116.5
1966	125.7	137.5	241.0	180.0	121.7
1971	129.7	137.1	238.8	182.4	128.4
1976	124.2	135.6	265.6	190.0	133.3
1981	129.5	140.8	264.4	182.8	137.6

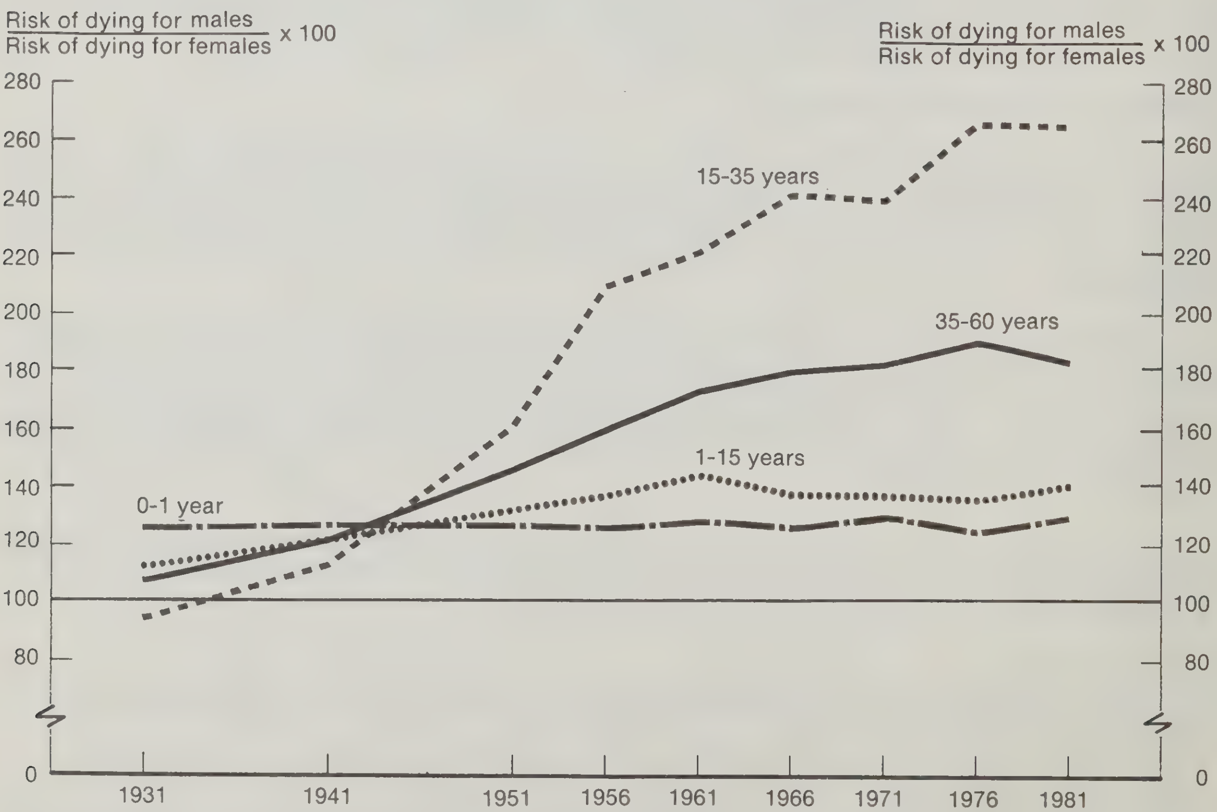
[1] For a given age interval:

$$\text{excess male mortality index} = \frac{\text{risk of dying for males}}{\text{risk of dying for females}} \times 100.$$

Source: Calculated from Statistics Canada, **Life Tables, Canada and Provinces** (for the periods 1930-1932 to 1980-1982).

Figure 21

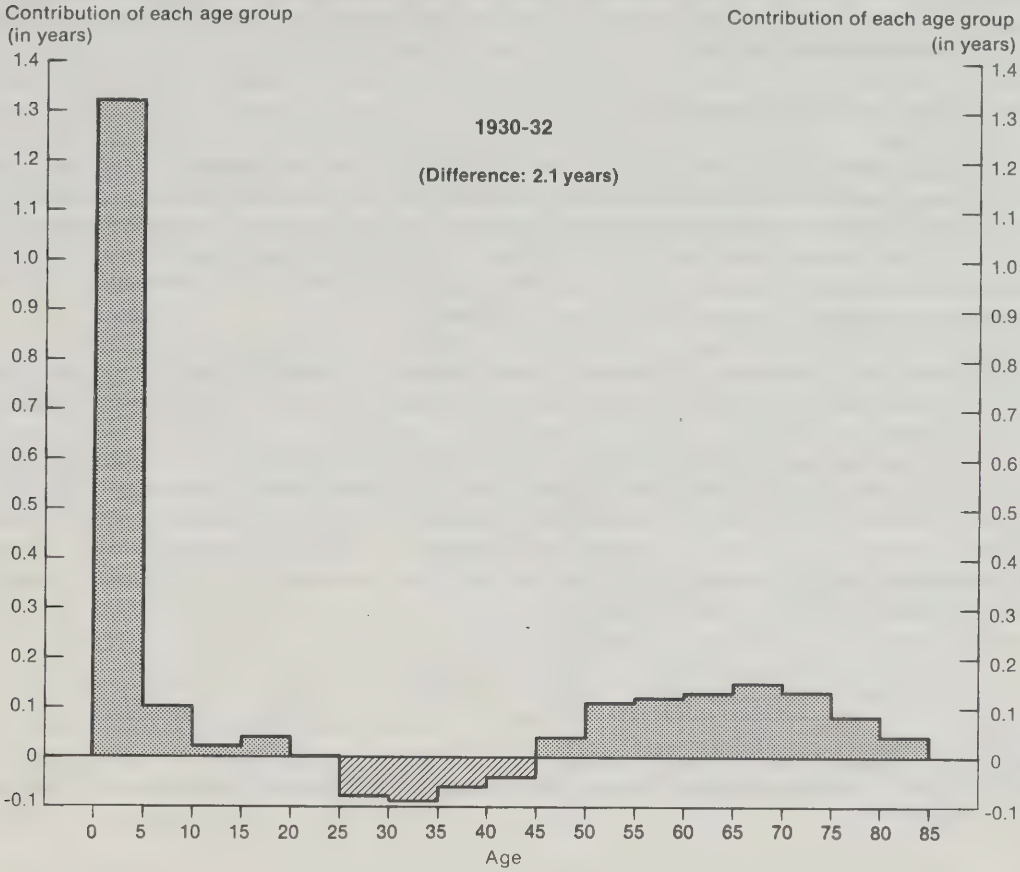
Differential Mortality by Sex for Selected Age Intervals, Canada, 1931-1981

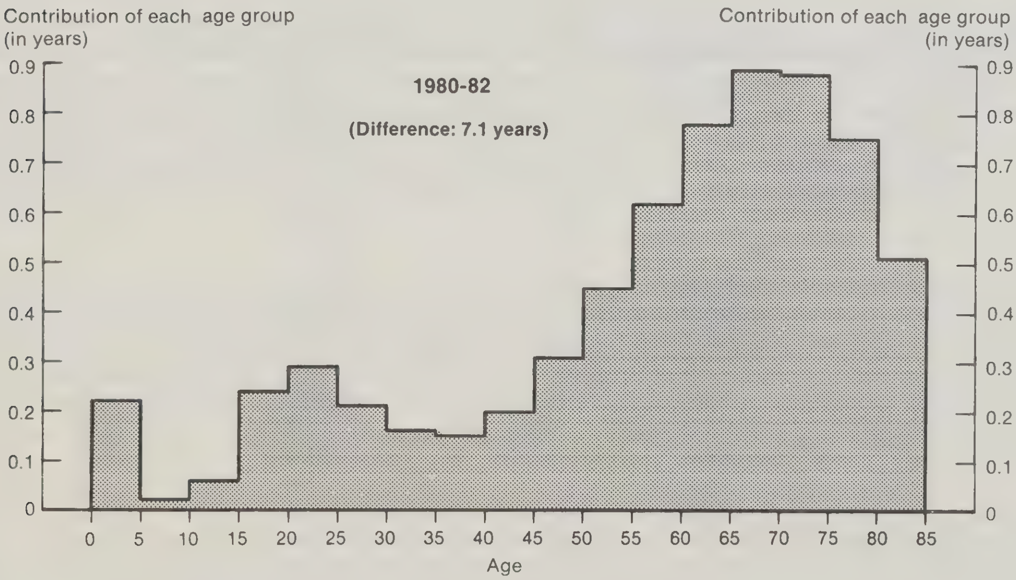


Source: Table 92.

Figure 22

Contribution of Mortality at Various Ages to the Difference in Life Expectancy of Men and Women, Canada, 1930-32 and 1980-82





Source: Calculated from D.B.S., Life Tables for Canada and Regions, 1941 and 1931, Catalogue 84-515 and Statistics Canada, Life Tables, Canada and Provinces, 1980-1982, Catalogue n° 84-532.

The current age-specific structure of excess male mortality in Canada is typical of that observed in developed countries. Graphically, this shows up as a bimodal curve, with a maximum around age 20 and another around age 55 (Figure 23). In the first case, mortality is three times higher among men, with this difference being mainly linked to traffic accidents. The second maximum - an index equal to 200 - would be due to the consequences of differential behaviour by sex: use of tobacco and alcohol, etc.

Factors of Excess Male Mortality[63]

Studying excess male mortality in religious teaching orders, where living conditions differ little according to sex, Madigan observed that, in 1955, mortality was higher among men and that this excess mortality was comparable to that observed for the American population as a whole. This led him to attribute excess male mortality to a lower resistance to degenerative diseases, that is, to biological causes. However, use of tobacco, a lifestyle factor whose role in mortality differences has since been demonstrated, was not isolated by Madigan.[64]

The foregoing is a good reflection of areas of concern in research into excess male mortality: distinguishing the part played by biological factors from that played by environmental factors.

The role of biological factors should probably not be neglected since, in periods of life when environmental factors have little (or no) effect, there is already excess male mortality. This is the case for intra-uterine[65] and perinatal mortality, in particular for the neonatal component. Studies by Bourgeois-Pichat show that, assuming elimination of all deaths attributable to exogenous causes, there would still be a gap between the life expectancies at birth of both sexes; this was estimated at 6.5 years for Norway in 1973.[66]

63 See Pressat, R., "La surmortalité des hommes", **Le Concours Médical**, 95, 2, January 13, 1973, pp. 287-290.
64 Madigan, F.C., "Are Sex Mortality Differentials Biologically Caused?", **Milbank Memorial Fund Quarterly**, 35, 2, April 1957, pp. 202-223.
65 French, F.E. and Bierman, J.M., "Probability of Fetal Mortality", **Public Health Reports**, 27, 1962, pp. 835-847.
66 Bourgeois-Pichat, J., "Future Outlook for Mortality Decline in the World", **Population Bulletin of the United Nations**, No. 11, 1978, pp. 25-26.

TABLE 93. Trends in Life Expectancy at Birth by Sex, Canada, 1931-1981

Year[1]	Males	Females	Difference
	(1)	(2)	(3) = (2)-(1)
		years	
1931	60.0	62.1	2.1
1941	63.0	66.3	3.3
1951	66.3	70.8	4.5
1956	67.6	72.9	5.3
1961	68.4	74.2	5.8
1966	68.8	75.2	6.4
1971	69.3	76.4	7.1
1976	70.2	77.5	7.3
1981	71.9	79.0	7.1
1931-1981	**+ 11.9**	**+ 16.9**	**+ 5.0**

1 In Canada, life tables are calculated using data for three-year periods. Thus, 1931 designates the period 1930-1932, 1941 the period 1940-1942, etc.
Source: See source, Table 92.

However, a great many studies emphasize the importance of lifestyle in attempting to explain excess male mortality. In a classic study, Retherford[67] stressed the role of tobacco smoking. One of the conclusions of a study by Waldron,[68] for example, is a good indication of the type of results yielded by some recent research: behavioural differences are more important than physiological differences, when it comes to sex-specific mortality. According to this author, three-quarters of excess male mortality in the United States may be explained by causes (heart disease, lung cancer, emphysema, accidents, cirrhosis of the liver, suicide) which are associated with behaviour judged socially more acceptable for men, for example an aggressive attitude in competitive situations, more dangerous working conditions, alcohol abuse and, until recently, smoking. A simple method makes it possible to calculate the share of each cause of death in the increase in excess male mortality. For example, Vallin has calculated that in France, between 1950 and 1978, 60% of the increase in excess male mortality between 15 and 24 years of age is attributable to traffic accidents.[69]

The existence of mortality differences by social class is well established. It would also appear, however, that the extent of mortality differentials by sex also varies from one social category to another. An example of this is given in a recent study on urban Canada, for the 1970-72 period.[70] An examination of the highest and lowest income groups showed higher excess male mortality among the less privileged. Excess mortality differences are particularly pronounced for lung cancer, accidents and violence, cirrhosis of the liver and alcoholism and, in most cases, these differences are the result of important variations in male rates by income category.[71] Thus, overall, the causes of death responsible for mortality differentials by sex are also those most responsible for variation in the level of excess male mortality from one income category to another.

Lifestyle would then appear to have a predominating influence and in this connection, it is noteworthy to find the lowest excess male mortality indices at ages (infancy and old age) when the lifestyles of males and females are probably the least different (Figure 23). The near-disappearance of infectious diseases has given an increasing importance to the individuals' lifestyle.

The Increase in Excess Male Mortality

It seems paradoxical that excess male mortality continues to increase while, at the same time, lifestyle differences by sex have tended to decrease.

This is basically due to two phenomena. On the one hand, the causes of death that are on the decline are those for which there was only a slight difference according to sex, or an excess female mortality (death associated with childbirth, infectious diseases and tuberculosis, for example). On the other hand, in the case of rising risks for women (smoking and alcohol use, for example), the effects are not yet fully manifest, given the fact that health problems are highly dependent on the length of exposure to risk: from this point of view, there is a significant temporal lag between the male and female populations. It is, however, reasonable to expect an eventual decrease in the life expectancy differences by sex; life tables for the 1980-82 period already indicate the onset of such a decrease.

It is worth noting that the existence of an important excess male mortality and its increase over time have consequences for the health system. To cite one among several possible examples, the high excess mortality of the male population, combined with a higher average age at marriage for men, gives rise to a large number of widows in the female population. This is probably not a negligible contributor to the particularly high proportion of elderly women living alone (Table 94). This situation might explain, at least in part, the longer average length of their stays in hospital.

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67 Retherford, R., "Tobacco Smoking and the Sex Mortality Differential", **Demography**, Vol. 9, 2, May 1972, pp. 203-216.

68 Waldron, I., "Why Do Women Live Longer than Men?", **Social Science and Medicine**, Vol. 10, 1976, pp. 357-358.

69 Vallin, J., "Tendances récentes de la mortalité française", **Population**, 38, 1, January-February 1983, p. 99.

70 Millar, W.J., "Sex Differentials in Mortality by Income Level in Urban Canada", **Canadian Journal of Public Health**, Vol. 74, 5, September-October 1983, Table IV, p. 331.

Figure 23

Excess Male Mortality Index by Age and by Causes of Death, Canada, 1980-82

(1) $\frac{\text{Risk of dying for males}}{\text{Risk of dying for females}} \times 100$

Source: Calculated from Statistics Canada, Causes of Death, catalogue 84-203 (1980-1981 and 1982) and Statistics Canada, Life Tables, Canada and Provinces, 1980-1982, Catalogue 84-532, May 1984, pp. 16-19.

TABLE 94. Percentage of the Aged (Age 65 and Over) Living Alone, by Sex, Canada, 1951-1981

Year	Males	Females	Total
		percentage	
1951[1]	–	–	9.2
1961	9.4	15.2	12.4
1971	11.1	24.3	18.4
1981	13.0	32.2	24.0

1 Not available by sex.
Source: From 1951, 1961, 1971 and 1981 Censuses of Canada.

Excess Male Mortality, Excess Female Morbidity and Health

The coexistence of excess male mortality and excess female morbidity[72] may, at the outset, appear contradictory. In fact, according to Pressat, the second phenomenon might, at least in part, explain the first.[73]

72 This was recently confirmed by the Canada Health Survey, **op. cit.**, pp. 109-114.
73 The following was drawn, in part, from Pressat, R., **op. cit.**, p. 290.

The availability of an efficient health system makes the responsiveness of individuals a factor of longevity. But men and women have different attitudes towards disease, and their willingness to seek medical help depends on the often subjective manner in which they evaluate their own health status.

An American study, the National Health Survey, revealed that women more often complain of minor ailments, such as palpitations, headache, insomnia, nightmares, tremors, etc., than do men. Even though these symptoms do not necessarily reflect a poor state of health, they trigger a series of early preventive or curative measures by those concerned. The fact that women take such measures more frequently and earlier, means that they benefit more from scientific progress which has increased longevity. It should be noted that these behavioural differences also have a sociocultural origin: women's contacts with the health care system, for example, are more frequent by virtue of the fact that contraception, pregnancy, childbirth, as well as child-raising have become medical matters.

The foregoing casts doubt on the **validity** of the excess male mortality index when one wishes to compare the health status of the male and female populations, but it does conveniently summarize differences in mortality.

The excess male mortality index is nevertheless useful in public health, since a particularly high index often reflects a difference in the intensity or length of exposure to certain health risks, whether these are past or present. Classic examples of this are tobacco and alcohol use. In extreme cases, the index could thus be a **reliable** indicator, insofar as it would be the symptom of major health problems. For example, it is noteworthy that, among the countries where the greatest differences are observed between male and female life expectancies, one finds those countries where the rate of alcoholism is notoriously high, such as Finland, France and the U.S.S.R..

III TECHNICAL DISCUSSION

Calculating the Excess Mortality Index

The excess male mortality index may be calculated using death rates or death probabilities.

Table 95 gives an example of the first approach. The data used in the calculation are the numbers of deaths by age and the average population during the year (in Canada, that estimated or enumerated on June 1st). The index is the ratio of the male death rate to the female death rate, the result being expressed by taking the female death rate as the base which is made equal to 100. In the case of the 20-24 age group, one may say that, in 1981, the frequency of male deaths was 3.2 times higher than that of female deaths.

Using life tables, published every five years by Statistics Canada, it is possible to calculate probabilities of dying for various age intervals and by sex. The ratio of the male probability to the female probability, expressed as a percentage, is a second way of obtaining the excess male mortality index. According to the calculation shown in Table 96, one may for example state that, among the survivors at their 15th birthday in a synthetic birth cohort experiencing the risks of dying measured in 1981, males have a 2.7 times higher probability than women of dying in the next 20 years, i.e. before their 35th birthday.

It should be noted that, for a given year, the two methods of calculation will not give **strictly** equal results. In addition, trends in the excess male mortality index may be influenced by variations in either the male or the female rate, although in practice there is a simultaneous variation of both rates. Therefore, a worsening of excess male mortality would, in itself, only tell how male mortality is evolving compared to female mortality.

The results obtained using death probabilities depend, as Bourgeois-Pichat has shown, on the age interval chosen. Using a one-year interval, the index reaches a maximum and then tends towards 100, while using instantaneous death probabilities yields an excess male mortality index

TABLE 95. Calculation of the Excess Male Mortality Index Using Deaths Rates, Selected Age Groups, Canada, 1981

Age group	Males			Females			Excess male mortality index
	Deaths	Population (June 3)	Death rate (per 1,000)	Deaths	Population (June 3)	Death rate (per 1,000)	
	(1)	(2)	(3)=[(1)/(2)] x 1,000	(4)	(5)	(6)=[(4)/(5)] x 1,000	(7)=[(3)/(6)] x 100
0- 4 years	2,476	914,400	2.7	1,832	868,900	2.1	128.6
5- 9 years	302	912,000	0.3	219	865,000	0.3	100.0
15-19 years	1,622	1,182,000	1.4	519	1,132,900	0.5	280.0
20-24 years	1,917	1,174,200	1.6	540	1,169,400	0.5	320.0
50-54 years	4,750	621,600	7.6	2,563	621,800	4.1	185.4
55-59 years	7,064	568,300	12.4	3,870	611,400	6.3	196.8
All ages	**97,055**	**12,067,600**	**8.0**	**73,974**	**12,274,100**	**6.0**	**133.3**

Source: Calculated from Statistics Canada, **Causes of Death, 1981**, Catalogue 84-203, Ottawa, 1983, and Statistics Canada, **Intercensal Annual Estimates of Population by Sex and Age for Canada and the Provinces, 1976-1981**, Catalogue 91-518, Ottawa, September 1983, Table 6.

TABLE 96. Calculation of the Excess Male Mortality Index Using Life Table Probabilities, Canada, 1980-82

Age interval x, x + a	Death probabilities		Excess male mortality index
	Males	Females	
	(1)	(2)	(3)=[(1)/(2)] x 100
	per 100,000		
0- 1 years	1,092	843	129.5
1-15 "	569	404	140.8
15-35 "	3,741	1,037	264.4
35-60 "	13,722	7,508	182.8
60-85 "	75,727	55,049	137.6

Source: Calculated from Statistics Canada, **Life Tables, Canada and Provinces, 1980-1982**, Catalogue 84-532, May 1984, pp. 16-19.

that increases constantly with age.[74] The first of those results is artificial: since annual probabilities q_x are always less than 1, and tend towards 1 at the end of life both for males and females, excess male mortality obviously tends to disappear. In reality, there is a regular increase with age in the excess mortality of males, and thus of the index.

Cross-sectional and Longitudinal Approaches

This last point deals with the graphic representation of excess male mortality indices and the questionable interpretations that are occasionally suggested.[75]

Let us take the example of population aging, that is, the increase over time of the **proportion** of elderly persons in the population. It has been established that the main cause of this phenomenon is the lowering of fertility. However, other things being equal, it is the lowering of mortality that produces an increase in the **number** of elderly persons from one cohort to another, and the greater aging of the female population is due to the more favourable mortality conditions enjoyed by women.

Differential mortality by sex produces an imbalance in the size of the male and female populations as was already mentioned when looking at census results (Figure 5, Descriptor D-09). It was noted that, while the sex ratio remained greater than 100 up until about age 45, it subsequently dropped rapidly, giving a good illustration of the effects of excess male mortality during the second half of life.

The foregoing thus renders trends in excess male mortality after age 45 particularly interesting; they may be measured by indices using probabilities taken from the various life tables published since 1931. Plotting the results obtained on a graph, one has, for each year of observation, a curve that represents the age-specific trend of the excess male mortality index. Looking at Figure 24a, it can be seen that:

- the excess male mortality index peaks between ages 50 and 60;
- excess male mortality increases over time.

These results should nevertheless be interpreted with caution. At a given age, the various points on each curve are not directly comparable, since:

- the individuals involved belong to different birth cohorts;
- with the increase over time in the excess mortality, a given curve in effect compares individuals belonging to birth cohorts with low excess male mortality (those aged 80 in 1971, for example) with persons from cohorts with higher excess mortality (those aged 45 in 1971).

Figure 24a therefore only gives, for selected years (1931, 1941, ... 1981), the level of excess male mortality observed at various ages. **It does not trace the development of this excess mortality throughout the life of a cohort** (or group of cohorts), i.e. of those individuals born during a given year (or period). This interpretation would constitute a classic error, that of confusing **cross-sectional** and **longitudinal** data. To avoid this error, all the points pertaining to individuals belonging to the same group of cohorts should be joined. This is how the solid-line curves of Figure 24b were obtained; on this chart, the curves from Figure 24a are shown as broken lines.

An examination of this new graph shows that excess male mortality:

- is indeed increasing if one moves from older to more recent cohorts;
- evolves with age, but in a more pronounced fashion than is indicated by cross-sectional data;
- culminates at a certain age, although this age seems higher than would be suggested by Figure 24a.

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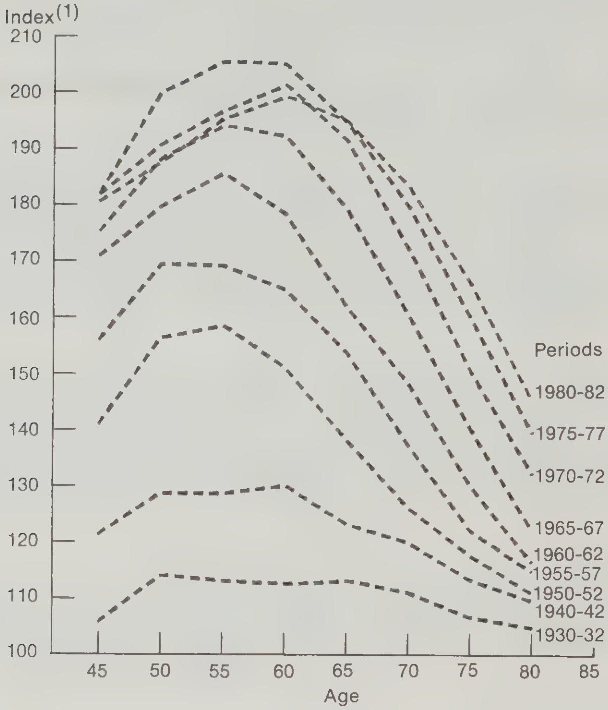
74 See Bourgeois-Pichat, J., "Future Outlook for Mortality Decline in the World", **op. cit.**, graph IV, p. 26.

75 The following is based on pages 157 to 160 in Desjardins, B. and Légaré, J., "Le vieillissement de la population du Québec: faits, causes et conséquences", **Critère**, 16, Winter 1977, pp. 143-169.

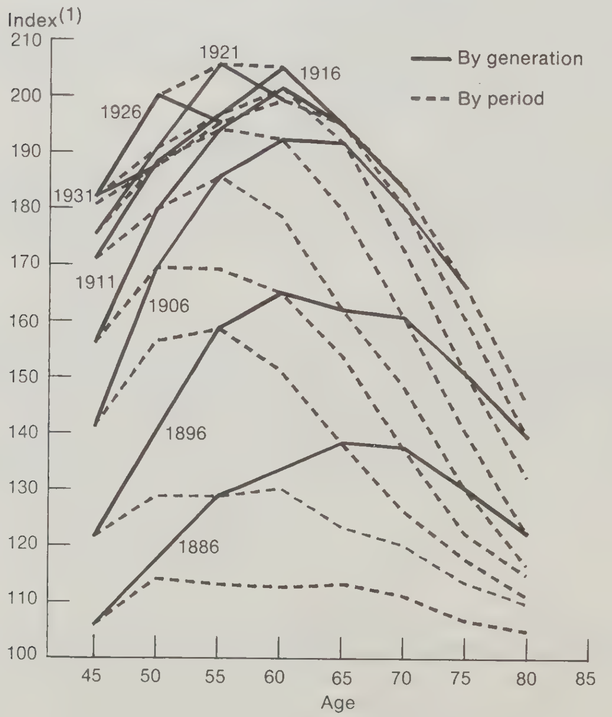
Figure 24

Excess Male Mortality Index, After Age 45, Canada

a) By Age, 1931-1981



b) By Age and Birth Cohort, 1886-1931



(1) $\left[{}_5q_x(M)/{}_5q_x(F)\right] \times 100$, i.e. $\dfrac{\text{Risk of dying for males}}{\text{Risk of dying for females}} \times 100$

Source: Calculated from Statistics Canada's life tables (1930-1932 to 1980-1982)

CONCLUSION

This study has dealt with a number of statistical indices which should be of use to those interested in public health. Some important aspects of their use will now be discussed.

Function of a Descriptor

Many works dealing with public health begin by a discussion of the state and growth of the population.[1] This is no accident, since it is difficult to imagine how health policies and programs could reasonably be developed without first having a good understanding of the population to be served and how it is evolving.

In any case, demographic reality often imposes constraints which cannot easily be ignored. The recent drop in the birth rate, for instance, has already caused the closing of many obstetrics and gynecology departments. If this decline continues, it will bring about a major shift in the demand for medical and hospital services towards the elderly, and this shift will necessitate far-reaching readjustments in the delivery of care as well as in the training and assignment of health professionals.[2] Such constraints constitute an additional incentive to study carefully the demographic situation in the coming years.

As a consequence the first part of this study dealt with the presentation of the main indices used by demographers in the overall description of the population state and population processes. Most of these demographic descriptors have been so widely used that their original definitions and functions have not always been preserved, resulting in an often deficient or entirely erroneous interpretation. This is why the principles and methods behind their development was first studied, thus increasing the understanding of the measure obtained using each index.

Function of an Indicator

Demographic indices are also used in public health for another reason: they provide a very useful indication of the health of the population. The second part of the study examines the use of demographic descriptors as health indicators.

For decades now, some mortality indices have been used as indicators of the health level of populations. These are the crude and standardized death rates, the infant mortality rate and life expectancy at birth. There are several reasons for this:

- mortality is negatively correlated to the health level of the population,
- reducing premature mortality in order to ensure that the greatest possible number of persons enjoy a complete life-span, is a permanent objective for public health authorities,
- of all the data that might potentially be used in developing an indicator, only mortality data are collected in a continuing and exhaustive manner.

Effective control of the deterioration of health status does not consist only in preventing or delaying a fatal outcome, it also consists in maintaining or restoring the ability to lead a normal existence. Because of the progress in therapeutic methods and the growing predominance of degenerative diseases, it would appear that the first objective is often easier to achieve than the second. It therefore becomes necessary to design new indicators which integrate data on mortality and disability, such as life expectancy in good health and quality-adjusted life expectancy.

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1 For a recent example, see Madden, T.A., Turner, I.R. and Eckenfels, E.J., **The Health Almanac**, New York, Raven Press, 1982, 355 p.

2 For further discussion of this, see for example: Boulet, J.-A. and Grenier, G., **Health Expenditures in Canada and the Impact of Demographic Changes on Future Government Health Insurance Program Expenditures** (Discussion Paper No. 123), Economic Council of Canada, Ottawa, 1978, 98 p., and Lefebvre, L.A., Zsigmond, Z. and Devereaux, M.S., **A Prognosis for Hospitals: the Effects of Population Change on the Need for Hospital Space, 1967-2031**, Catalogue 83-520E, Statistics Canada, Ottawa, 1979, 92 p.

Since indicators of the health level of the population are by definition very general, they obviously do not suffice to guide decision-making and action. Other indicators, in particular those which enable the principal health problems to be identified and classified, must be added. By following the sequence of disease-related events in order to respect as closely as possible the range of possible interventions, indicators may be chosen such as the prevalence of risk factors and of precursors, the incidence and prevalence of disease, the cause-specific death rate and the prevalence of disability disaggregated by the appropriate conditions or injuries. The impact of these problems on the health level of the population may be estimated by calculating their effect on life expectancy and life expectancy in good health.[3]

Useful Disaggregations [4]

To satisfy the requirements of those responsible for decisions and actions in the area of public health, indicators should be calculated for the populations of the various political and administrative divisions of the country. There are some widely recognized limits to this territorial disaggregation: epidemiological data become less available and all indices become less dependable when the size of the population is too small.

In addition, since the nature and frequency of health problems vary considerably during the life cycle, it is useful to consider indicators of the health of the principal demographic groups making up a population: children, adolescents and young people, adults and the elderly.[5] Most of the indicators presented in this study lend themselves well to such an age-specific disaggregation.

Since the health of individuals is partially dependent on their physical, social or cultural environment, indicators should also be calculated to take into account characteristics such as place of residence, education, occupation, income, ethnic origin, etc. Current statistics only rarely provide this information, which must therefore be drawn from special studies or specific surveys. These data demonstrate that not all persons have the same chances of living a healthy life.

Two Examples of Disaggregation

One of the major concerns in public health is the persistance of the gap that separates the poorest members of a population from the other social classes. It was long believed that this gap came into being in the early 19th century, but work in historical demography has shown that social inequality in the area of mortality was present well before the industrial revolution. It is quite remarkable that social inequality with respect to disease and death has endured in spite of all the changes in pathology and the measures adopted to ensure universal access to health services.

Various explanations have been given for the persistence of this inequality:[6]

1. it results from the very unequal distribution of wealth and of other elements of well-being;[7]
2. it is caused by the fact that attitudes and behaviour harmful to health have survived longer in underprivileged groups;
3. it reflects the relationship between the health status of persons and their occupational and social mobility;

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3 On this question, see: Robine, J.M. and Colvez, A., "Espérance de vie sans incapacité et ses composantes: de nouveaux indicateurs pour mesurer la santé et les besoins de la population", **Population**, 39, 1, January-February 1984, pp. 27-45, and Colvez, A. and Blanchet, M., "Potential Gains in Life Expectancy Free of Disability: A Tool for Health Planning", **International Journal of Epidemiology**, 12, 2, June 1983, pp. 224-229.

4 See: Johnston, D.F., **Basic Disaggregations of Main Social Indicators** (O.E.C.D. Social Indicator Development Programme series, Special Study No. 4), Paris, O.E.C.D., 1977.

5 See, for example, United States. Department of Health, Education and Welfare, **Healthy People**, the Surgeon General's Report on Health Promotion and Disease Prevention, Washington, U.S. Government Printing Office, 1979, 177 p., and Levasseur, M., **Des problèmes prioritaires** ("La santé des Québécois" Series), Québec, Conseil des affaires sociales et de la famille, 1983, 189 p.

6 For further details, see: Townsend, P. and Davidson, N. (Eds.), **Inequalities in Health. The Black Report**, Harmondsworth, Penguin Books, 1983, pp. 112-134.

7 For an example dealing with mortality, see M. Roemer's analysis, quoted in Brouard, N., **et al.**, "L'influence des politiques sociales et de santé sur l'évolution future de la mortalité," **Population**, Vol. 38, 6, November - December, 1983, pp. 1075.

4. interpretation of the phenomenon must take into account the fact that highly underprivileged groups represent an increasingly smaller proportion of the total population.

The choice to be made out of these various interpretations is not a purely academic one, since it determines to a great extent the choice of measures to be taken.

Table 97 gives the values of three indicators of health level for the urban population of Canada broken down by income quintile. Gaps between categories increase when one moves from total years lived to years lived free of disability, and they are always greater for males than for females. These results confirm that the most serious health problems are more likely to be found in the most underprivileged groups.

TABLE 97. Health Level by Income Quintile and by Sex, Canada, 1978

Life expectancy	Total	Income quintile				
		Lowest	Second	Third	Fourth	Highest
		in years				
Males						
Life expectancy at birth(e_0)	70.8	67.1	70.1	70.9	72.0	73.4
Quality-adjusted life expectancy	66.0	59.4	64.8	66.8	68.1	69.7
Disability-free life expectancy	59.5	50.0	57.9	61.1	62.6	64.3
Females						
Life expectancy at birth(e_0)	78.3	76.6	77.6	78.5	79.0	79.4
Quality-adjusted life expectancy	72.3	69.7	71.1	72.7	72.8	74.8
Disability-free life expectancy	63.6	59.9	61.8	64.3	63.5	67.5

Source: Adapted from Table 5.4 in Wilkins, R. and Adams, O.B., **Healthfulness of Life**, Montreal, Institute for Research on Public Policy, 1983, p. 98.

Once public health planners have identified sub-populations according to duration and quality of life, they may seek to determine what are the main obstacles to a longer and better life. This is another major concern: identifying and ranking the health problems of a population.

Traditionally, the importance of health problems was determined solely on the basis of their impact on mortality. The cause-specific death rate, life expectancy lost and, more recently, potential years of life lost, are examples of indicators which have long been used to identify and rank health problems.

Since individuals nowadays have a good chance of living through all the various stages of the life cycle, more importance is given to the quality of life. This is mainly due to the growing relative importance of chronic diseases in morbidity as a whole, and to the fact that an increase in life expectancy is not necessarily synonymous with progress in the health of the population. In fact, the United States has recently witnessed the coexistence of a decrease in mortality and a spectacular rise in disability.[8]

When identifying and ranking health problems, their impact both on the duration and on the quality of life should be taken into account. This approach was adopted for the United States population, and then for that of Quebec. Table 98 summarizes the results obtained in the latter case. For example, elimination of the principal health problem - diseases of the circulatory system - would bring about a gain of 3.53 years of life expectancy at birth for Quebecers (impact on mortality), but also a gain of 2.64 years of life expectancy in good health, i.e. free of disability (impact on activity restriction). The total impact on life expectancy in good health would accordingly be 6.17 years (see also I-12: Tables 52 and 53).

It should be noted that the method used by Dillard has the advantage of identifying problems (diseases of the musculoskeletal system, for instance) that are significant because of the disability they cause, but which would have gone unnoticed in the traditional approach where only mortality was taken into account. It is seen that taking into account activity restriction also has an effect on the ranking of health problems.

Toward a Synthetic Measure of the Health of Populations?

In the ideal situation, one would want a single index that would summarize all the health conditions existing in a population.

Life expectancy at birth has traditionally performed this function, as has infant mortality. It has been observed that the former is closely correlated to changes in the latter. Life expectancy is a measure based on a phenomenon - mortality - that is easy to apprehend and that corresponded to a major concern for public health authorities, i.e. prevention of premature mortality.

Priority is now oriented towards improving the quality of life rather than simply increasing its duration. This is due to the low levels that mortality has already reached, the slowing-down of progress in preventing premature death, and the growing importance of chronic diseases in total morbidity. "Life expectancy in good health" provides, at least in part, an answer to this relatively new concern of the health care system by offering a synthetic measure that takes into account the various states of health, from the most negative (death) to the most positive (total absence of disease and disability). Its simplicity of calculation and the disaggregations to which it lends itself make it an extremely useful measurement tool for health planners.

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[8] Colvez, A. and Blanchet, M., "Disability Trends in the United States Population 1966-1976: Analysis of Reported Causes", **American Journal of Public Health**, 71, 5, May 1981, pp. 464-471.

TABLE 98. The Main Diseases and Their Impact on Life Expectancy in Good Health, Quebec, 1980

Ranking of Diseases	Impact on mortality	Impact on activity restriction	Impact on life expectancy in good health
		in years	
1. Diseases of the circulatory system	3.53	2.64	6.17
2. Diseases of the musculo-skeletal system	–	3.51	3.51
3. Neoplasms	2.34	–	2.34
4. Accidents and injuries (not including suicides)	1.02	1.08	2.10
5. Diseases of the respiratory system	0.44	1.51	1.95
6. Mental disorders (including suicides)	0.50	0.81	1.31
7. Congenital anomalies and perinatal defects	0.95	–	0.95
8. Diseases of digestive system	0.36	0.28	0.64
9. Diabetes	0.17	0.14	0.31
10. Diseases of the nervous system and sense organs	0.17	0.12	0.29

Source: Table 1 in Conseil des affaires sociales et de la famille, **Objectif: santé**, Quebec, Éditeur officiel du Québec, 1984, p. 47.

With the development of "life expectancy in good health", an important step has been taken towards arriving at a synthetic measure of the health of populations. Further progress may be expected, and it is quite likely that future research will be hindered less by methodological problems than by gaps in available data. As in the case of life expectancy in good health, new indicators will most probably complement, rather than replace, "traditional" health indicators.

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DEMOGRAPHIC AND HEALTH INDICATORS

PRESENTATION AND INTERPRETATION

Yves Péron and Claude Strohmenger

Improving the level of health is a major concern both for governments, which allocate considerable resources to this goal, and for individuals, who benefit from a better quality of life.

Measuring the level of health has therefore become an important task for the health planner, and indices developed in demography provide a great many of the instruments used in this work. Growing interest in the health field has brought about ever-increasing and widespread use of these indices, as well as the development of new indices. It accordingly appeared useful to publish a systematic presentation of the principal demographic indicators of health.

The indices selected have been divided into two categories: demographic descriptors, which describe the state and change of the population to be served by the health care system, and demographic indicators of health, which are used to assess the level of health. To make this study easier to consult, the presentation of each index is made up of three parts:

- a brief description (definition and function of each indicator),
- an illustrative section (with a commentary showing the application and interpretation of the indicator),
- a technical discussion, featuring the assumptions and methodology underlying the calculation of the index.

Because of the format of the presentation, this manual should be particularly helpful to students, researchers and teachers in demography, public health, epidemiology, preventive and social medicine, and health economics. It is also intended for persons engaged in health planning and evaluation.